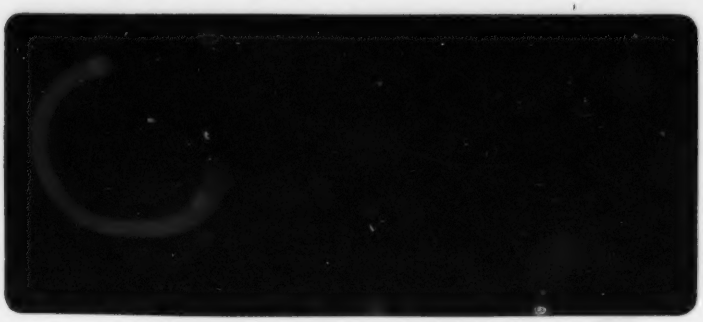

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I73062C

TP 9258E

R-CLASS ICEBREAKER TESTING REQUIREMENTS

May 1988

Prepared for

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- Ms. E. Cleroux

LANGUAGE NOTICE

Un sommaire en français de ce rapport est inclus avant la Table des matières.

Transport Canada / Transports Canada
Development / Développement

REPORT DOCUMENTATION FORM

1. Transport Canada Report No.	2. TDC Project No.	3. Recipient's Catalogue No.
TP 9258E	7027	

4. Title and Subtitle	5. Report Date
R-Class Icebreaker Testing Requirements	May 1988
	6. Performing Organization Report No. I73062C
7. Author(s)	8. Transport Canada File No.
I.F. Glen	D1460-245-2
9. Performing Organization Name and Address Fleet Technology Limited (formerly Arctec Canada Ltd.) 311 Legget Drive Kanata, Ontario K2K 1Z8	10. DSS File No. 11SD.T8200-7-7557 11. DSS or Transport Canada Contract No. T8200-7-7557/01-SD
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 200 René-Lévesque Boulevard West Suite 601, West Tower Montreal, Quebec H2Z 1X4	13. Type of Report and Period Covered Final (Feb. 88 - May 88) 14. Sponsoring Agency Code 7027
15. Supplementary Notes	16. TDC Project Officer M. Stenson

17. Abstract

A study has been performed to determine the need and requirements for full-scale icebreaking tests in support of research into R-Class icebreaker performance, and in particular the correlation of model and full scale performance data.

The study concludes that in order to improve the quality of field data to the point where direct correlation with model predictions can be made, significant development effort must be directed into defining environmental requirements and ship/ice interaction measurement techniques. Such work should be performed in advance of expensive full-scale trials. The trials proposed are confined to performance in level and ridged ice.

Also presented is an ideal ship trials program based on the current R-class schedule and the desired trials locations. Some modification of the current vessel deployment is anticipated in order to satisfy the need to conduct tests in thicker, stronger ice.

18. Key Words	19. Distribution Statement
R-Class, Full Scale Trials, Icebreakers, Institute for Marine Dynamics.	Limited number of copies are available from the Transportation Development Centre.

20. Security Classification (of this report)	21. Security Classification (of this page)	22. No. of Pages	23. Price
Unclassified	Unclassified	70	Nil

TDC CDT 79-005
Rev 86

Canada

Transports Canada / Transport Canada
Développement / Development

FORMULE DOCUMENTAIRE DU RAPPORT

1. Nº du rapport Transports Canada	2. Nº de l'étude — CDT	3. Nº de catalogue du destinataire
TP 9258E	7027	

4. Titre et sous-titre	5. Date du rapport
R-Class Icebreaker Testing Requirements	mai 1988
	6. Nº du rapport de l'organisme exécutant
	I73062C
7. Auteur(s)	8. Nº de dossier Transports Canada
I.F. Glen	D1460-245-2
9. Nom et adresse de l'organisme exécutant	10. Nº de dossier — ASC
Fleet Technology Limited (formerly Arctec Canada Ltd.) 311 Legget Drive Kanata, Ontario K2K 1Z8	11SD.T8200-7-7557
	11. Nº de contrat — ASC ou Transports Canada
	T8200-7-7557/01-SD
12. Nom et adresse de l'organisme parrain	13. Genre de rapport et période visée
Centre de développement des transports (CDT) 200 ouest, boul. René-Lévesque Suite 601, tour ouest Montréal (Québec) H2Z 1X4	Rapport final (fév. 88 - mai 88)
	14. Code de l'organisme parrain
	7027
15. Remarques additionnelles	16. Agent de projet — CDT
	M. Stenson

17. Résumé

Une étude a été lancée afin de cerner les éléments d'un programme d'essais en vraie grandeur devant être réalisé dans le double but de connaître les performances réelles du brise-glace de classe R et, plus particulièrement, d'arriver à faire la corrélation entre résultats théoriques, obtenus sur maquettes, et résultats pratiques, obtenus in situ.

L'étude a montré que, en vue d'obtenir des résultats pratiques d'une qualité telle que leur corrélation avec les résultats théoriques puisse se faire directement, il faut consentir un effort important afin de définir le cadre physique dans lequel ces essais devront se dérouler, et cerner de plus près les techniques à utiliser pour mesurer la nature et l'étendue de l'interaction coque-glaces. Cette définition devra nécessairement précéder les essais in situ toujours coûteux. Les essais envisagés se limitent à des essais de performances dans des glaces uniformes et comportant des crêtes.

Le rapport donne les détails d'un programme d'essais in situ considéré comme idéal, tenant compte du calendrier des opérations normalement prises en charge par le brise-glace de classe R, ainsi que des sites sélectionnées pour les essais. Afin que ces derniers puissent avoir lieu dans des glaces de plus grandes épaisseur et résistance, le calendrier en question devra être légèrement modifié.

18. Mots-clés	19. Diffusion
Class R, essais in situ, brise-glace, Institut de dynamique marine.	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
Non classifié	Non classifiée	70	Aucun

CDT TDC 79-005 Rev 86

Canada

ACKNOWLEDGEMENTS

Fleet Technology Limited wish to acknowledge the contributions made by all those who attended the workshop. Special thanks are due to A. Keinonen of AKAC for his written contributions and advice, and V. Laskow, ARAD, and S. Mathews, Coldstream Maritime Inc., for their help. M. Stenson, the TDC Project Manager, is also thanked for his input and for his thorough monitoring of progress.

SUMMARY

The collection of quality full-scale data for ships operating in ice-covered waters remains a major requirement for the continued development of Arctic transportation technology. Full-scale data collection is time consuming and often it is difficult to ensure the necessary environmental conditions - thereby impacting the quality of results obtained. Nevertheless, it is only through well planned full-scale testing that a comprehensive understanding of the response of ships to the Arctic environment, and hence the relationships between model and full-scale data, can be obtained.

A study has been undertaken to determine the need for, and nature of full-scale R-Class icebreaker trial requirements in support of the calibration activities at the National Research Council's (NRC) Institute for Marine Dynamics, as well as the on-going scientific needs of Canada's marine industry.

The study solicited the opinions of a large number of Government, university and industry specialists, through a one-day workshop and subsequent discussions. The workshop provided a unique opportunity for qualified experts to voice their opinions on the subject. As is clear from the separately published minutes (Minutes from Transport Canada Trials Workshop, dated April 15th, 1988), there were many different opinions on the test needs and procedures. At the outset, there was little consensus in either the choice of vessel or scope of trials.

The main findings of the workshop indicate that in order to improve the quality of field data to the point that direct correlation with model tests is possible, significant development effort must be put into understanding the ship/ice interaction, determining the range and nature of ice properties to be measured, the techniques to be used, etc. This done, the trials themselves can proceed within a predefined scope, using standard instrumentation.

As a result, a plan has been developed for some basic ice performance tests. The plan includes test procedures, measurement requirements, an instrumentation plan, ship and trials schedules and proposed staffing levels. Detailed, practical test sheets and data recording sheets have been developed for use in the program. Cost of the reserve program, including development effort, is estimated at $700,000.00.

A full-scale trial schedule spanning some two weeks is determined, and the total program is estimated to run over two years with trials to be held in 1990. It is also shown that the normal R-Class operations may have to be modified a little to accommodate the trial requirements. In the meantime, it is recommended that research effort be directed to the development areas, in a timely fashion and in advance of the trials.

SOMMAIRE

Une des grandes considérations dans le développement ininterrompu des technologies relatives aux transports maritimes dans l'Arctique a été, et est toujours, la saisie de données de qualité par des essais en vraie grandeur dans des eaux chargées de glaces. Cet impératif se heurte cependant à une difficulté double; les essais demandent beaucoup de temps et les conditions environnementales requises pour obtenir des résultats de qualité sont rarement réunies. Or, c'est seulement un programme d'essais bien planifié qui peut permettre de cerner de près la nature et l'étendue de l'interaction coque-glaces et, par conséquent, de dégager le rapport pouvant exister entre les resultats théoriques, obtenus sur maquettes, et les résultats pratiques, obtenus in situ.

Afin d'appuyer les travaux de calage des modèles, effectués par l'Institut de dynamique marine du Conseil national de recherches, ainsi que les activités scientifiques de l'industrie maritime du Canada, une étude a été lancée dans le but de cerner les éléments d'un programme d'essais en vraie grandeur devant être réalisé par un brise-glace de classe R.

Pour cela, il a été organisé un atelier d'un jour auquel ont participé de nombreux on experts venus des milieux gouvernementaux, universitaires et industriels. Le débat que cet atelier a suscité a permis à ces experts d'exprimer leur opinion sur le sujet à l'ordre du jour. Comme le montre le compte rendu des débats daté du 15 avril 1988, ces opinions étaient aussi nombreuses que variées. Dès le début, on pouvait se rendre compte que les participants ne entendaient ni sur le choix du navire, ni sur la portée du programme des essais.

Le débat a quand même débouché sur l'importantes conclusions, notamment que, dans le but d'obtenir des résultats pratiques d'une qualité tel: que leur corrélation avec les résultats théoriques puisse se faire directement, il faut nécessairement approfondir davantage l'interaction coque-glaces, déterminer les propriétés des glaces à quantifier, les limites de la plage de mesure, les techniques de mesurage à utiliser, etc.; après quoi, les essais proprement dits pourront commencer, dans le cadre d'un programme bien défini, mettant en oeuvre une instrumentation standard.

La recherche a permis d'élaborer un programme visant un certain nombre d'essais de base dans les glaces; les détails de ces essais y sont précisés: modes opératoires d'essais et de mesurage, instrumentation, calendrier et main-d'oeuvre. De plus, des formules d'enregistrement des données et de compte rendu des essais ont été élaborés peur ce programme. Quant au coût du programme comprenant les travaux préparatoires, il a été estimé à 700 000 $.

Le calendrier des essais in situ s'étendra sur deux semaines environ, tandis que l'ensemble du programme, y compris les travaux préparatoires aux essais, doit en principe s'étendre sur plus de deux ans, les essais proprement dits commençant en 1990. Il a été également établi que le calendrier des opérations normalement prises en charge par le brise-glace de classe R devra être légèrement modifié pour faire place au programme considéré. Entre-temps, il est recommandé de procéder aux études préparatoires en temps opportun de manière à posséder toutes les données nécessaires avant le début du programme.

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1. INTRODUCTION

The collection of quality full-scale data for ships operating in ice-covered waters remains a major requirement for the continued development of Arctic transportation technology. Full-scale data collection is time consuming and often it is difficult to ensure the necessary environmental conditions - thereby impacting the quality of results obtained. Nevertheless, it is only through well planned full-scale testing that a comprehensive understanding of the response of ships to the Arctic environment, and hence the relationships between model and full-scale data, can be obtained.

A review of the need for full-scale testing of an R-Class icebreaker was recently conducted by Sable Maritime Limited on behalf of the Transportation Development Centre (TDC). The review concluded there was sufficient justification for further trials based on the limited range of ice properties achieved, the quality of ice and some instrumentation uncertainties in previous trials. NRC reports LTR-SH-383 of October 1984 supports the conclusions drawn by Sable Maritime Limited and adds that much more and better data from full-scale trials is needed.

This study has been performed for TDC under DSS Contract No. T8200-7-7557/01-SD the purpose of which was to identify the need for and objectives of a proposed full-scale icebreaker trials program and hence to develop a Trials Agenda. The principal objective of the proposed trials is to support the calibration of NRC's IMD, and while this project was funded and managed by TDC, it is to satisfy IMD's requirements that the project has been carried out.

This study solicited the views of interested and qualified government, industry and university experts through interviews and a one-day workshop. Subsequent to the workshop, minutes were produced and circulated, and the testing and trials requirements developed.

In the following sections, the outcome of this study is presented, comprising Trials Matrix, Agenda, Schedules, Recommended Action and Trials Tests Sheets are presented in Annex A.

The nature of the anticipated data presented herein changed as a result of the workshop and subsequent discussions, in that it became clear that the type of on-ice measurements could not be defined without further investigation. Existing methods, while providing a comparative index with previous work, are not necessarily relevant to the icebreaking mechanisms, nor to the model testing activity.

It is also to be noted that there was a considerable variation in opinion over the tests required, the scope of the program and the methods of testing, to the point where the results herein cannot fail to be opposed by some experts. In view of this, we have used our own extensive experience in both model testing and field testing to provide a Trials Agenda that we believe satisfies the need while recognizing the real constraints and practicalities of full-scale tests.

A presentation to Coast Guard is part of the study, and at the time of writing has not been given. In view of this, the tables and figures herein have been identified as 'exhibits'.

2. TRIALS, MEASUREMENTS AND DATA COLLECTION REQUIREMENTS

An overview of the proposed Trials Agenda is presented in the form of a matrix (see Figure 2.1). Minimum measurement/data recording needs are shown for each proposed trial.

It will be seen that the Scope of Trials has been restricted to continuous level icebreaking, ramming and manoeuvring, with an open water overload or 'tow test' as a high priority.

Significant measurements which are considered tasks in themselves are identified separately as they have separately identifiable objectives and a dedicated test team.

Figure 2.1

Trials/Data Collection Matrix

Priority	Test Number	RECORDINGS and OBSERVATIONS / DESCRIPTION	Ice Strength (to be determined)	Ice Thickness	Ice Salinity Profile	Ice Temperature	Ice Pressure* (see note 1)	Broken Ice Piece Size	Snow Wetness	Snow Density	Ridge Profile	Ice Failure Process Observ.	Ice Flow Around Hull U/W	RPM	Torque	Thrust	Power Setting (kW)	Rudder Angle	Rudder Stock Torque	Rudder Stock Bending	Ram Pressure	Ship Drafts	Ship Heading	Ship Speed	Ship Position	Friction Ice/Hull	Hull Surface Roughness	Towline Force	Torque, Thrust & RPM Towed Ship	Ship Motions	Accelerations
		TESTS																													
1	1	Continuous Level Icebreaking	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●				●	●	●		●				●	●
	2	Start Up Tests	●	●	●	●	●		●	●				●	●	●	●									●					
	3	Overload Test												●	●	●	●	●				●	●					●	●		
	4	Ramming Tests - Thick Level Ice - Ridges	●	●	●	●	●	●			●	●	●	●	●	●	●					●		●	●					●	●
2	5	Breaking Out of Channel		●								●		●	●	●		●				●	●	●	●						
	6	Manoeuvring Tests	●	●	●	●	●	●				●	●	●	●	●	●	●	●	●	●		●	●	●			●			
	7	Ice Loads on Rudder/Steering	●	●				●						●	●	●	●	●	●	●	●			●							
		MEASUREMENTS																													
1	M1	On Ice Measurements	●	●	●	●	●	●	●	●																					
	M2	Friction Measurements	●	●	●	●			●	●																●	●				
	M3	Snow Effect on Resistance	●	●	●	●	●		●	●		●														●	●				
	M4	Ship-Ice Interaction	●	●			●	●				●																			
2	M5	Under Water Viewing of Icebreaking	●	●				●					●																		
	M6	Icebreaking Resist. Components	●	●	●	●	●	●				●																			

1. Use of ice pressure sensors is an area for development effort prior to trial.

3. TRIALS AND DATA COLLECTION SHEETS

Trials Sheets for each of the tests and measurements proposed have been developed (see example). These define objectives, target environment and data collection requirements and therefore provide the basis for the Trials Agenda.

Data collection sheets have been drafted for use by trials team members and are included with each trial sheet.

Space has been allocated for such information as special logistics needs, location of trials, etc. In some cases, this detail will need to be completed at a time closer to the actual trials date.

These documents are designed as working documents for use in the trials program and are presented in Annex A.

EXAMPLE OF TRIALS SHEET

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No. T1
CONTINUOUS LEVEL ICEBREAKING	Priority 1

Objective To determine the power required to move the vessel at continuous, steady speed through a continuous level ice cover, and to analyze the resistance.

Description
Constant power runs for 2 - 3 ship lengths in up to six ice thicknesses and a variety of snow conditions.

Time Required 3-4 days (not necessarily continuous)

Measurements Required

	RPM	Others
Thrust	2	Friction
Torque	2	Ice Thickness Properties
Ship Speed	1	Ship's Draft
		Broken Ice Piece Size

Environment Required		Ice Thickness Range Required
Level snow free ice	$\sigma_f \simeq 400$ kPa	0.5 -0.7 m and >1 m
	$\sigma_f \simeq 200$ kPa	<1 m
	$\sigma_f \simeq 600$ kPa	0.5 - 1 m

Possible Locations
Saguenay River - March; Labrador East Coast - Feb.-Apr.; Pond Inlet - January.

Special Logistic Requirements	Responsible Agency
	IMD

Measurement Options
Ship's Speed (Doppler, Microwave Positioning, Camera)
Thrust (Mitchell Bearing Pressure, Other)
In Ice Pressure
Hull/Ice Friction

Preparatory Studies Needed

None

Notes

Analysis of data should yield speed, power curves for ice thickness and strength, deduce thrust and compare with model data in form of thrust/speed/thickness/strength plots; also snow effects.

4. INSTRUMENTATION

The shipboard instrumentation proposed comprises recording of propulsion parameters, motions and rudder data as well as ship's position and heading.

No hull strain measurements are proposed, nor is a hull panel recommended. This instrumentation is suitable both for the purposes of model/full-scale comparison and for assessment of overall ship performance.

This shipboard system is quite straight forward, the only item requiring further definition being the method for thrust measurement. IMD propose the use of pressure sensors in the Michel thrust bearings. Previous techniques have involved the use of instrumented thrust pads. The ability of a pressure sensor to measure dynamic thrust response must be checked, and an optimum system selected for measuring thrust.

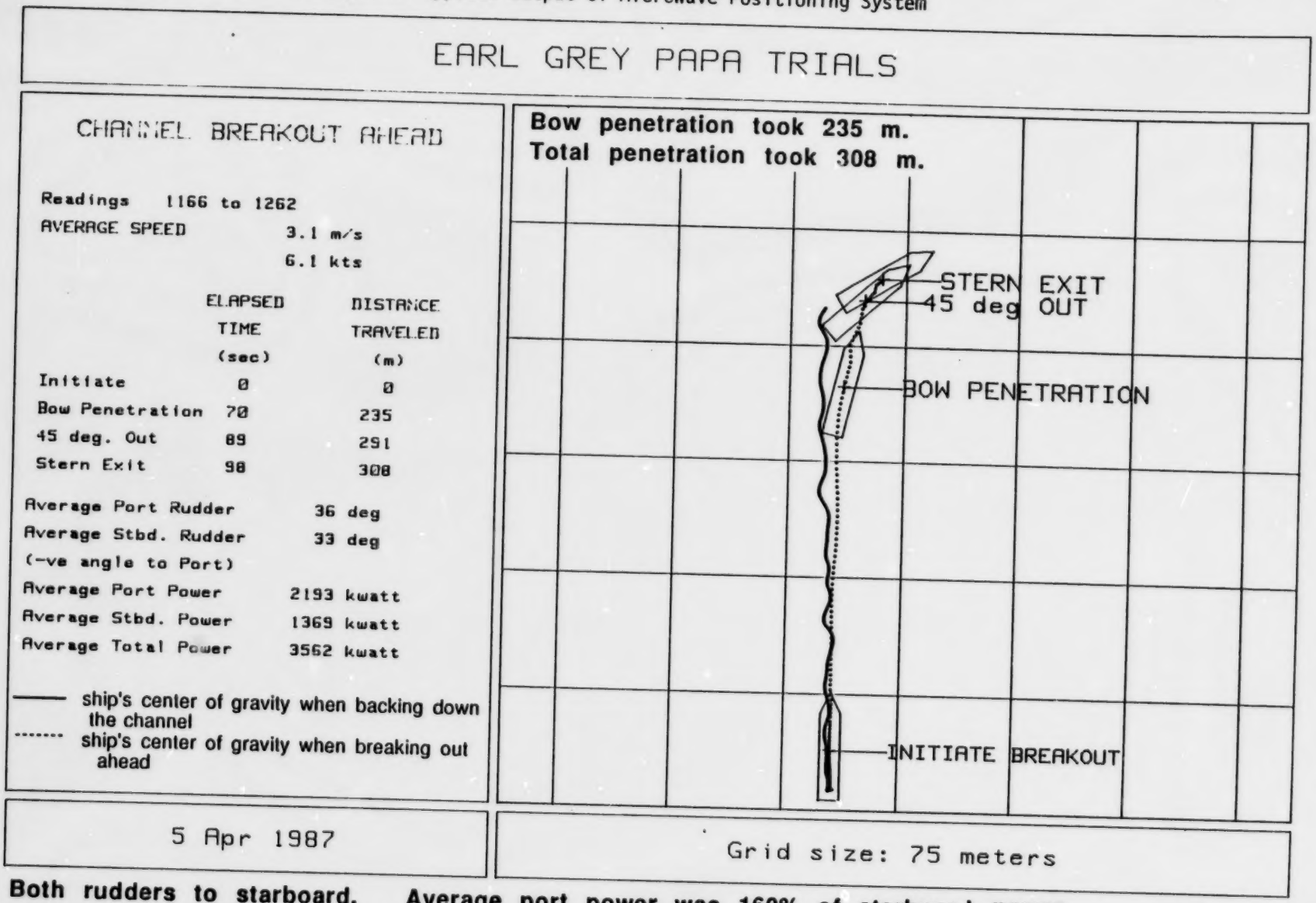
While Test #3 (overload) will provide thrust data for combinations of ship's speeds and rpm, direct measurement of thrust is vital for investigation of propeller/ice interaction, and further understanding of thrust deduction propulsive coefficient in ice.

We recommend the use of a microwave positioning system, especially for ramming and manoeuvring tests as these provide accurate time based ship's position, speed and heading automatically in digital form synchronized with ship's parameters (see Figure 4.1 for typical output) from which measurements can readily be reduced and analyzed. The system saves at least one onboard team member and much analysis time.

We recommend a digital scanning rate on the propulsion system of at least 200 Hz.

A typical data acquisition system is shown in diagrammatic form (see Figure 4.2) and the proposed shipboard system, including video camera is indicated in the overall layout shown in Figure 4.3.

Figure 4.1 - Example of Typical Output of Microwave Positioning System


EARL GREY PAPA TRIALS
CHANNEL BREAKOUT AHEAD
Readings 1166 to 1262
AVERAGE SPEED 3.1 m/s
6.1 kts
ELAPSED TIME (sec)
DISTANCE TRAVELED (m)
Initiate 0 0
Bow Penetration 70 235
45 deg. Out 89 291
Stern Exit 98 308
Average Port Rudder 36 deg
Average Stbd. Rudder 33 deg
(-ve angle to Port)
Average Port Power 2193 kwatt
Average Stbd. Power 1369 kwatt
Average Total Power 3562 kwatt
ship's center of gravity when backing down the channel
ship's center of gravity when breaking out ahead
Bow penetration took 235 m.
Total penetration took 308 m.
STERN EXIT
45 deg OUT
BOW PENETRATION
INITIATE BREAKOUT
5 Apr 1987
Grid size: 75 meters

Both rudders to starboard. Average port power was 160% of starboard power.

Figure 4.2
Typical Data Acquisition System

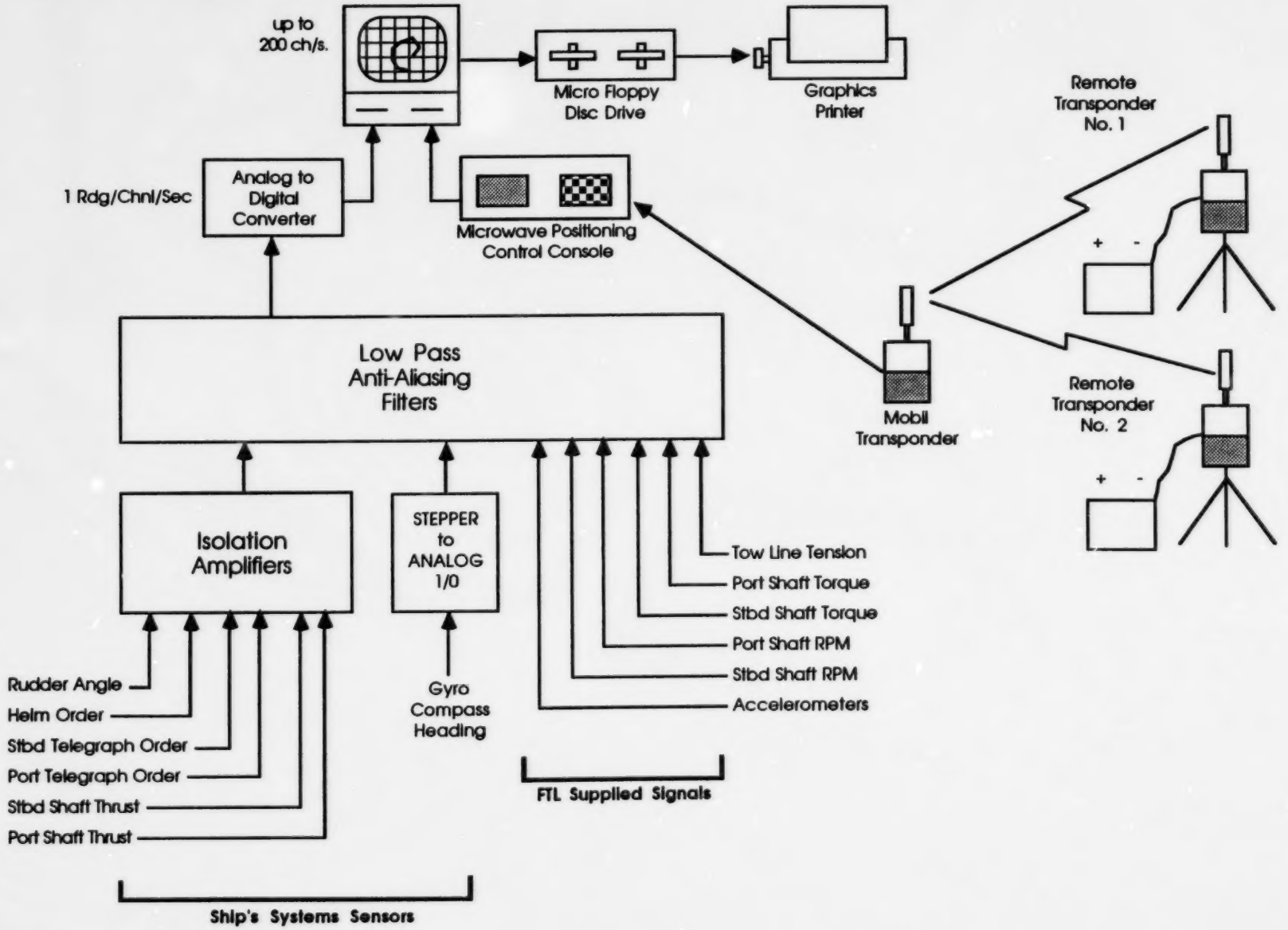
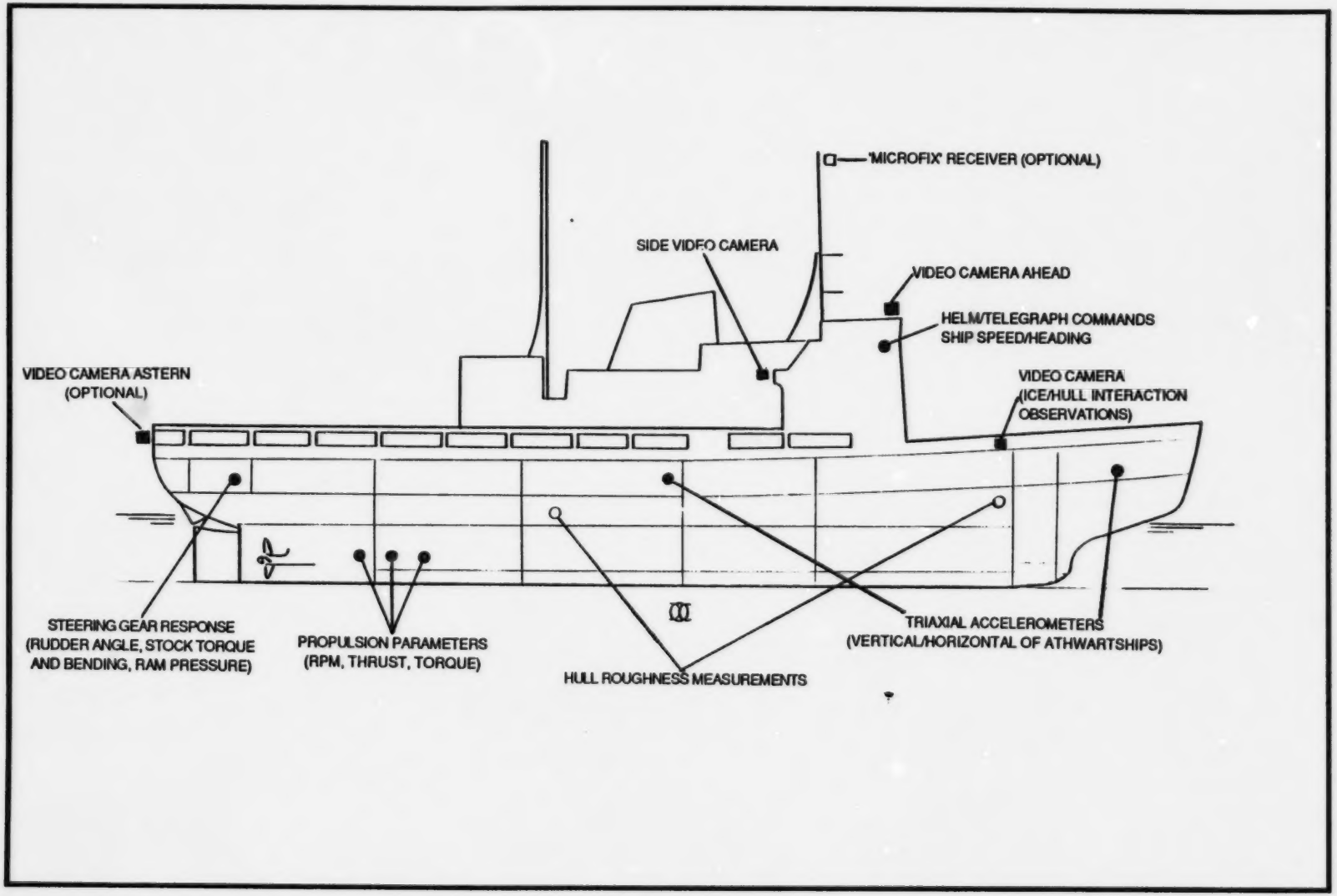


Figure 4.3
Instrumentation Layout



5. LOCATIONS AND SCHEDULES

An important issue in this study was to identify what the ship requirement will be in terms of location and schedule, in order to approach Coast Guard for ship availability.

Location requirements were based in the target ice conditions, the highest priority of which was to fill gaps in the existing level ice data. The gaps in the current data were shown to be:

- Thickness 0.5 - 0.7 m and $\geq$1m - strength 400 kPa
- Thickness $\leq$1m - strength 200 kPa.

Recent R-Class model tests have been conducted at 400 kPa and 800 kPa bending strength equivalent. While 800 kPa first year level ice is not readily found in the field, it was decided also to target 600 kPa ice at all thicknesses.

In this section, we present a typical R-Class schedule, location of suitable target ice conditions by time of year (accounting for CASPPR Zones) and from this develop an ideal test schedule.

Figure 5.1

Typical Program For "R" Class Icebreakers

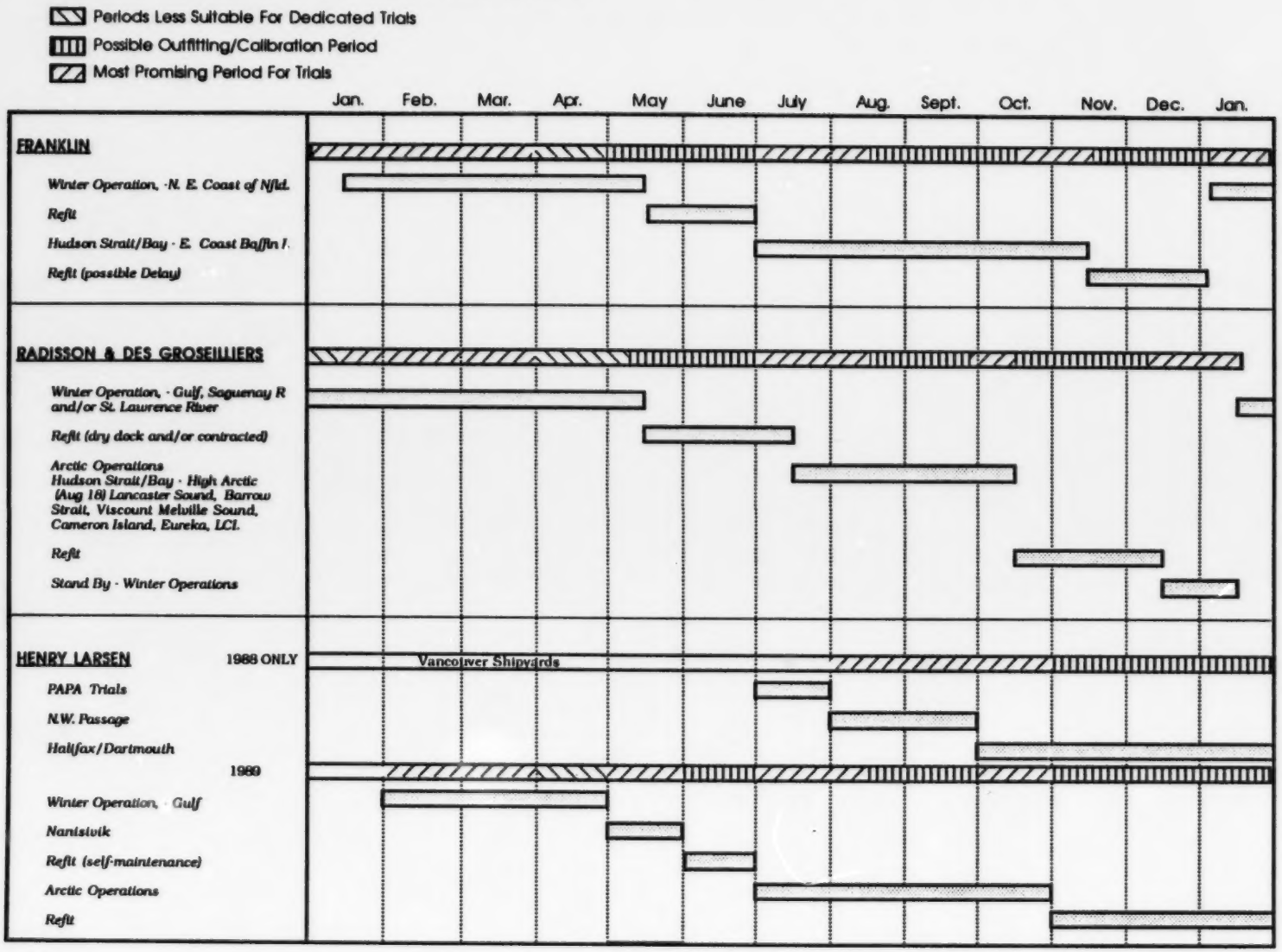


Figure 5.2

Location Map for Suitable Environmental Conditions

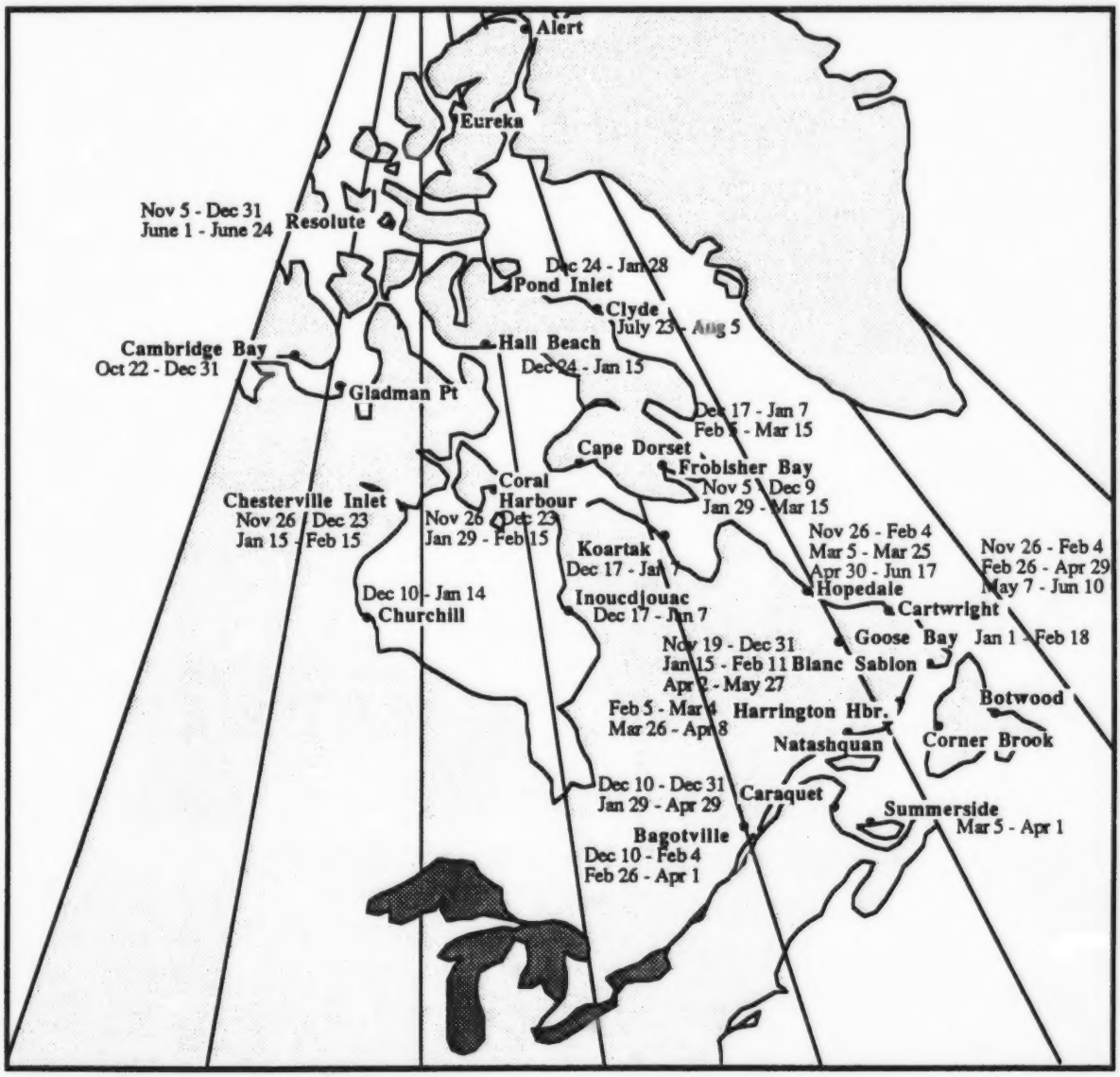


Figure 5.3

Location/Ice Condition/Time Matrix for Possible R-Class Full Scale Trials

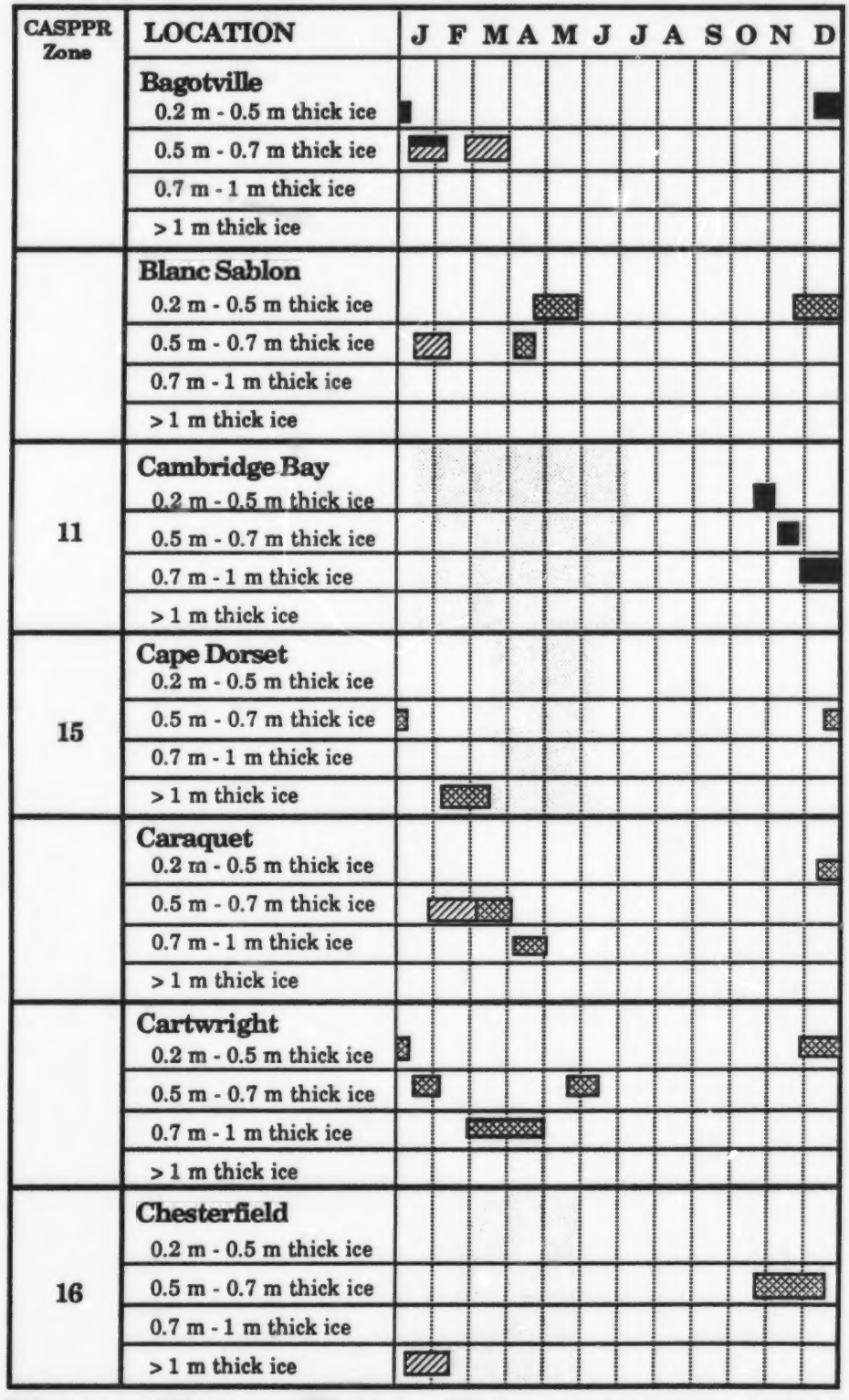

CASPPR Zone
LOCATION
J F M A M J J A S O N D
Bagotville
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
Blanc Sablon
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
11
Cambridge Bay
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
15
Cape Dorset
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
Caraquet
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
Cartwright
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
16
Chesterfield
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
200 kPa
400 kPa
600 kPa
Times not accessible due to CASPPR Zones

Figure 5.3 (continued)

Location/Ice Condition/Time Matrix for Possible R-Class Full Scale Trials

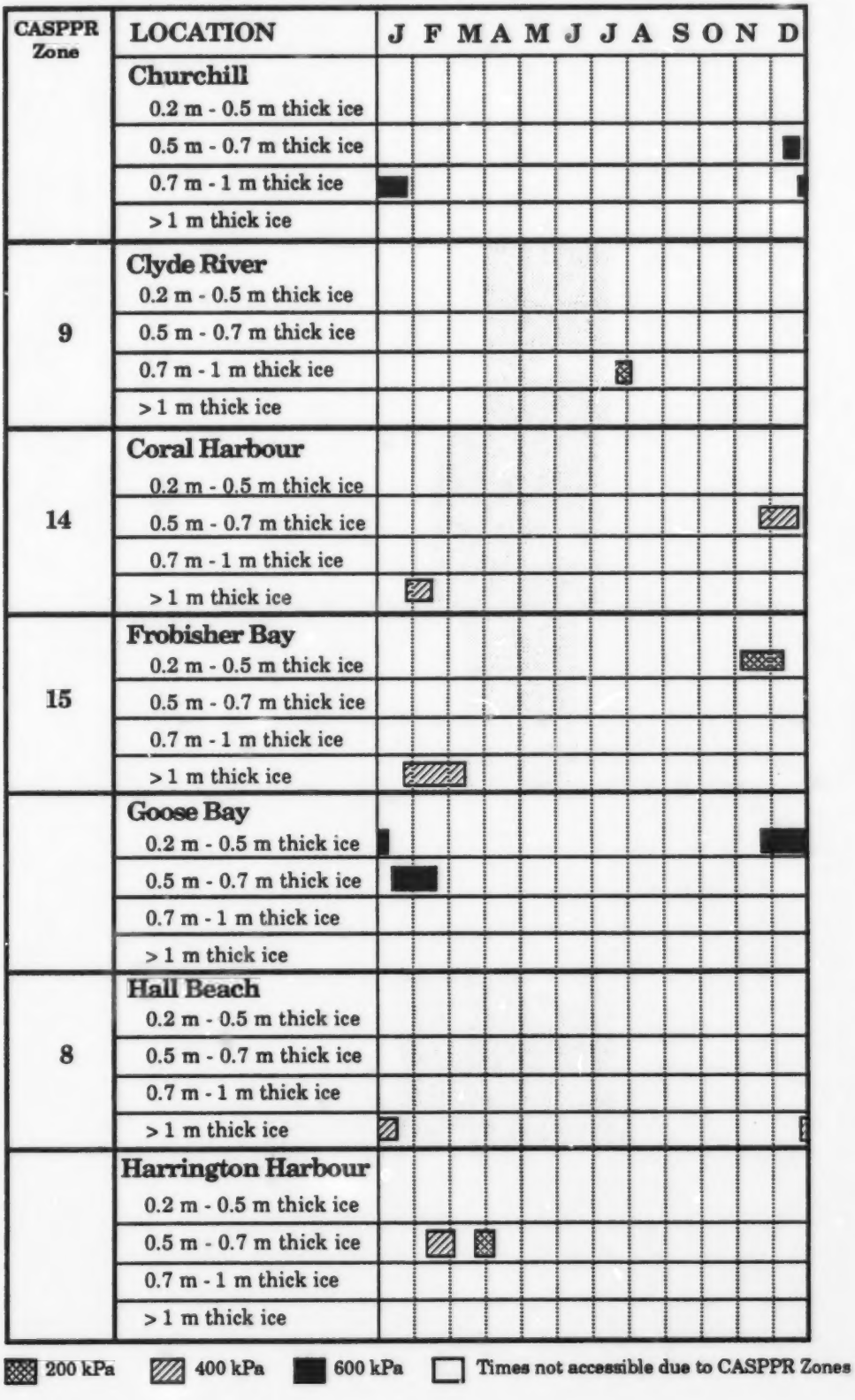
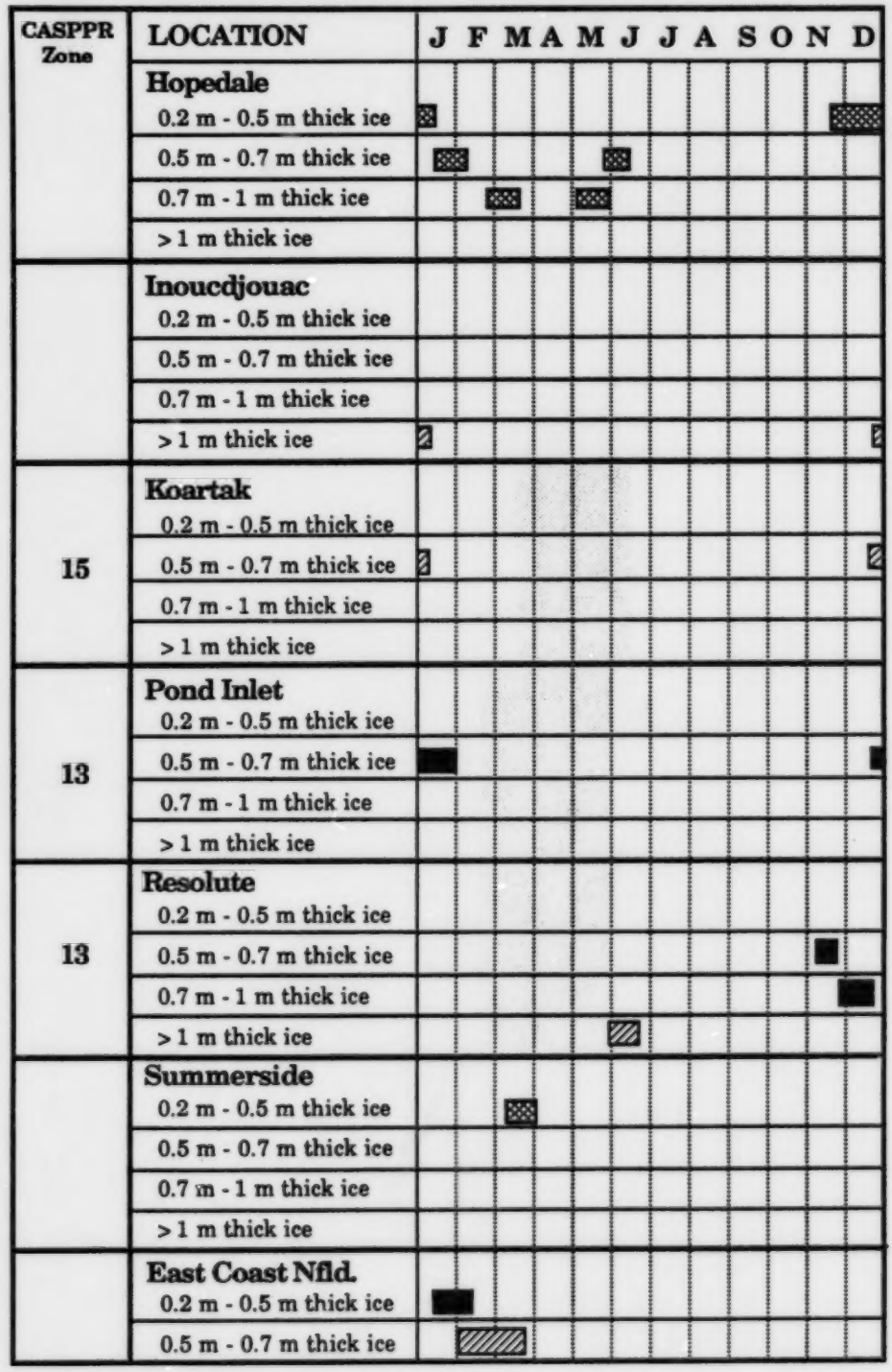

CASPPR Zone
LOCATION
J F M A M J J A S O N D
Churchill
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
9
Clyde River
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
14
Coral Harbour
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
15
Frobisher Bay
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
Goose Bay
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
8
Hall Beach
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
Harrington Harbour
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
200 kPa
400 kPa
600 kPa
Times not accessible due to CASPPR Zones

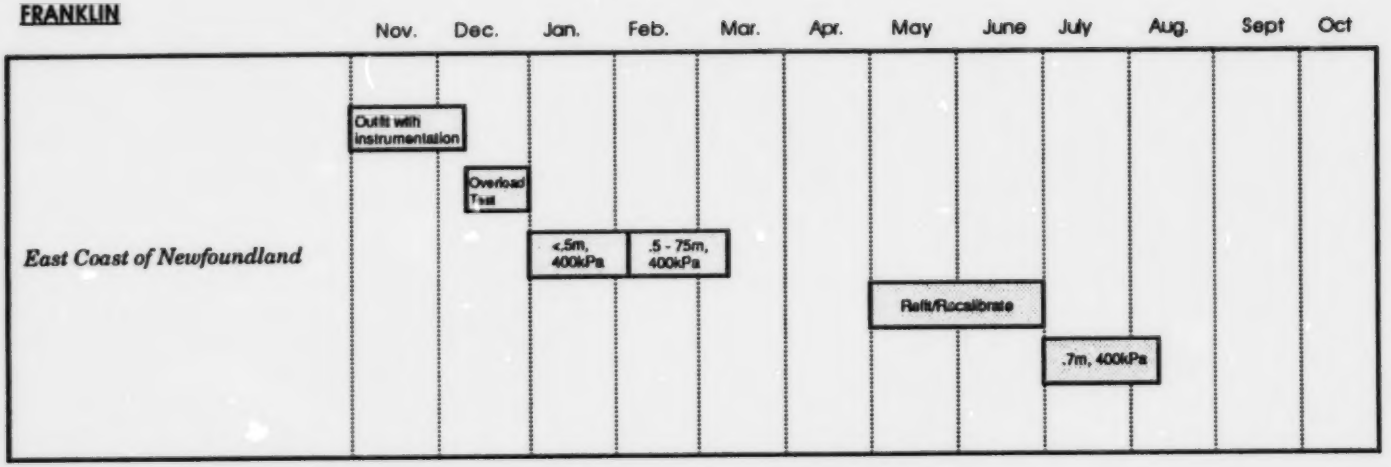
Figure 5.3 (continued)
Location/Ice Condition/Time Matrix for Possible R-Class Full Scale Trials


CASPPR Zone
LOCATION
J F M A M J J A S O N D
Hopedale
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
Inoucdjouac
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
15
Koartak
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
13
Pond Inlet
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
13
Resolute
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
Summerside
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice
0.7 m - 1 m thick ice
> 1 m thick ice
East Coast Nfld.
0.2 m - 0.5 m thick ice
0.5 m - 0.7 m thick ice

200 kPa 400 kPa 600 kPa Times not accessible due to CASPPR Zones

Figure 5.4

Trials Program Based on Existing Ship Programs



Notes on FRANKLIN Program:

The operations of FRANKLIN are such that she is likely to operate in ice types that are similar to that for which data is available. She is unlikely to operate in ice over .75m, of any strength and in ice stronger than 400 kPa of any thickness. This analysis concludes that the FRANKLIN is not the ideal choice of vessel, based on her current operations, to fill gaps in "R" Class data.

Figure 5.4 (continued)

Trials Program Based on Existing Ship Programs

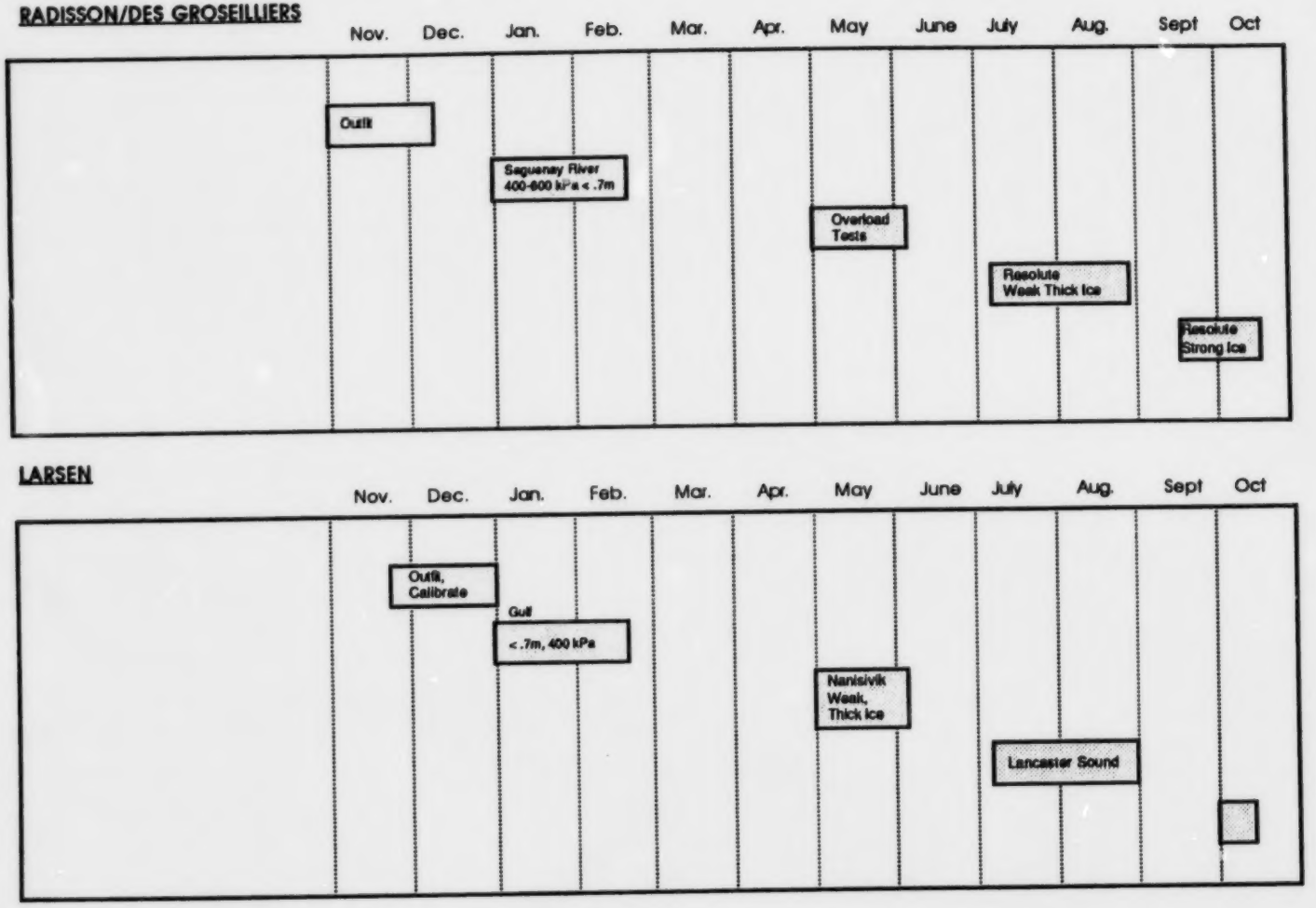


Figure 5.5

Proposed Program To Achieve Goals

(Requires achievable change to normal Ship routing)

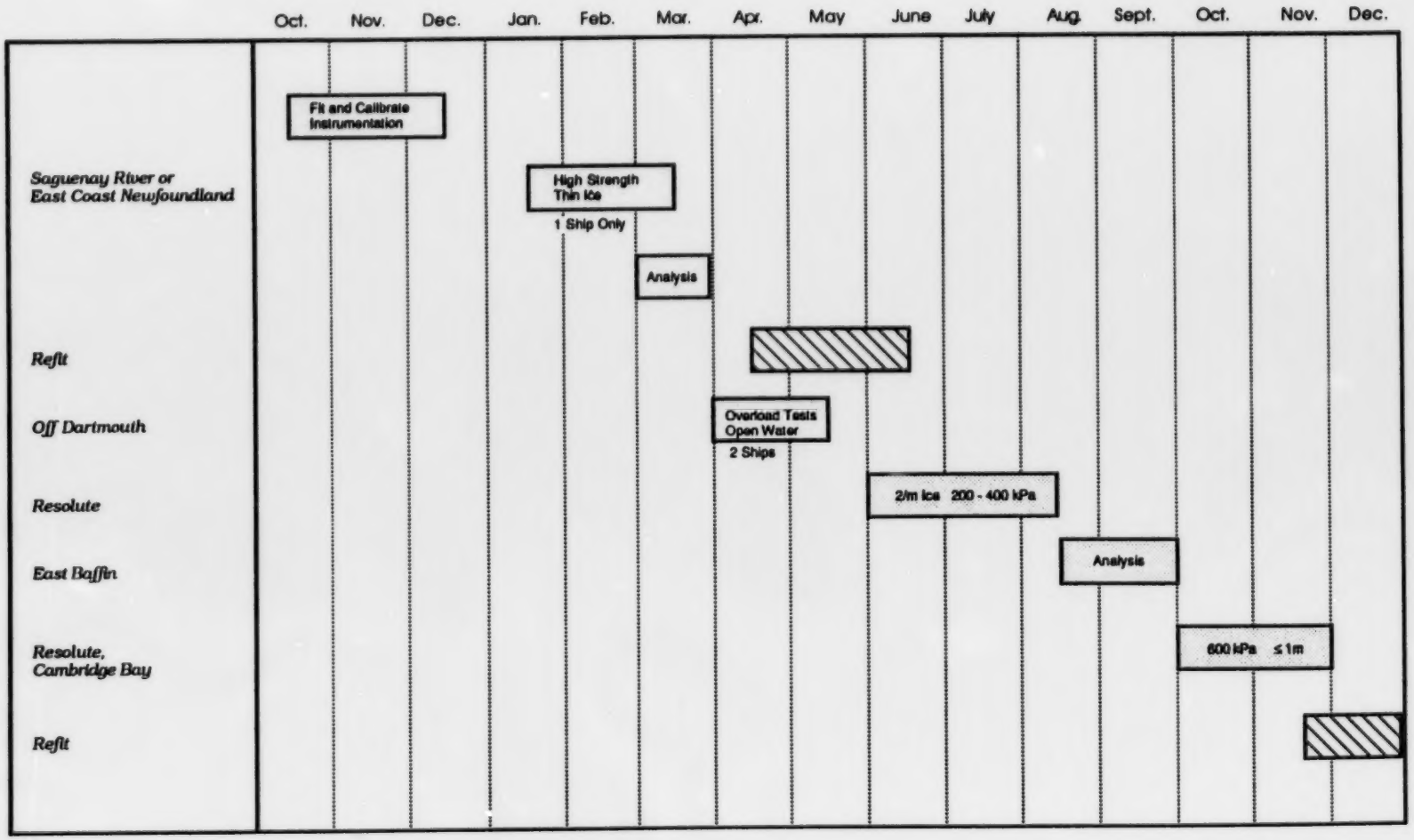
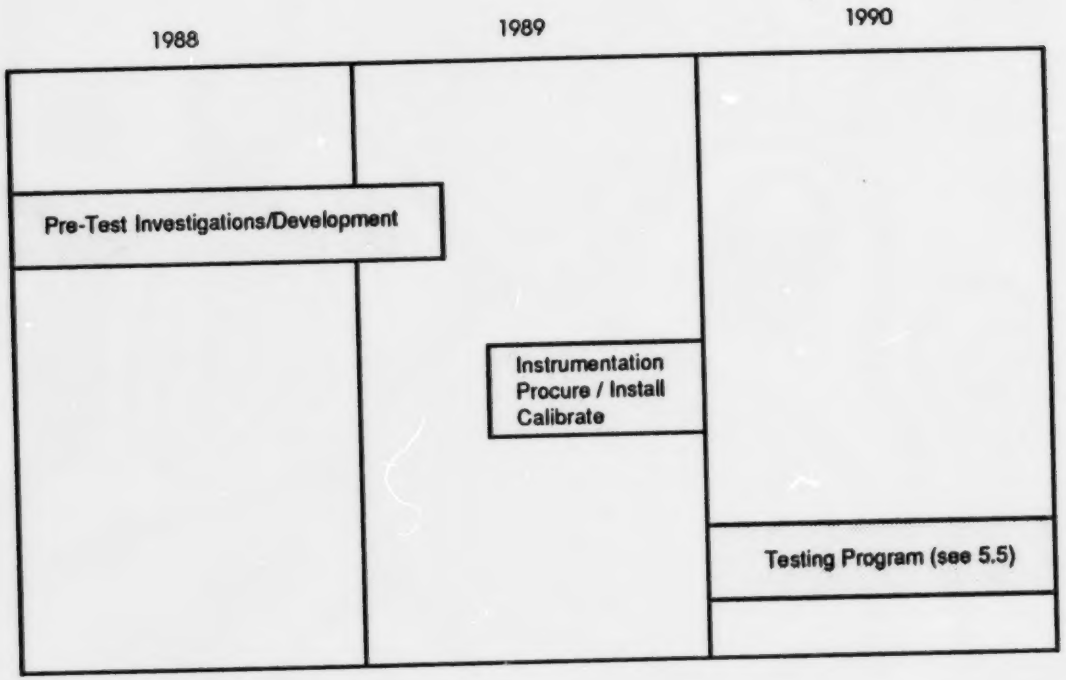


Figure 5.6

Recommended Program



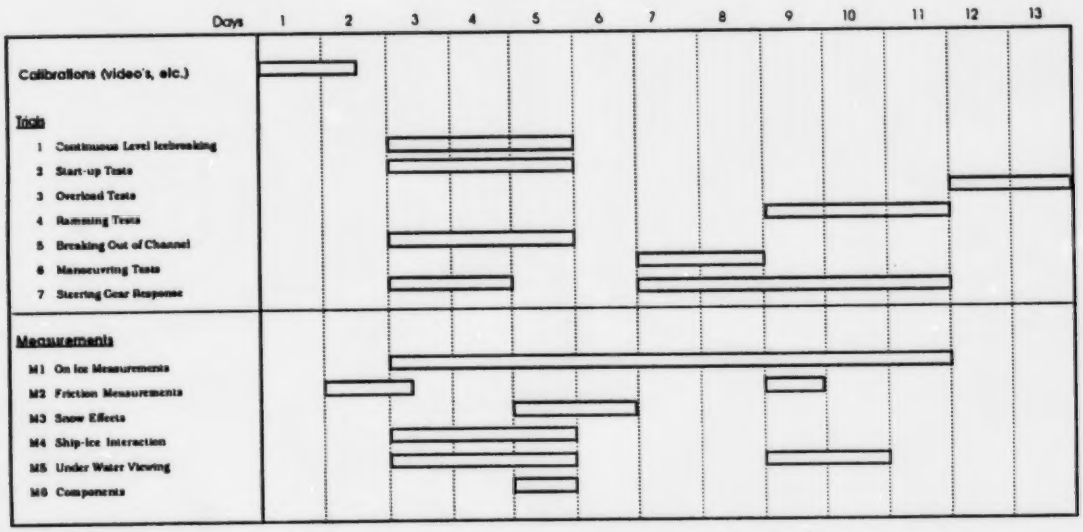
6. TEST SCHEDULE

In the previous section a total trials program schedule based on the ship program was developed and presented.

In this section, we indicate the minimum schedule for the actual trials period, assuming all trials were conducted consecutively.

The purpose of this is to give an indication of parallel activities and the minimum ship time required to assist in developing a base cost option.

Figure 6.1
Ideal Trials Schedule



7. STAFFING

7.1 Trials Manning Levels

The manning for the trials proposed herein is not based on the minimum number of persons necessary to conduct the tests, but rather on the diverse interests who wish to participate. The proposed staffing levels are based on the division of responsibility to specific aspects of the trials.

TABLE 7.1
SUMMARY OF MANPOWER REQUIREMENTS

TEST/ MEASUREMENT	PROPOSED STAFFING	ORGANIZATION	DAYS ONBOARD	TOTAL MANDAYS	COMMENTS
T1 Continuous Ice Testing	3	Contractor	4	12	Same People
T2 Start-Up Test	3	Contractor	4	12	
T3 Overload Test	3	Contractor	2	6	May be done separately. Needs 2nd vessel & OW.
T4 Ramming Tests	3	Contractor	3	9	
T5 Breaking out of Channel	3	Contractor	4	2	Same team as for 3.
T6 Manoeuvring	3	Contractor	3	9	
T7 Ice Loads on Gear	3	Contractor	7	21	Same team for T1, etc.
M1 On Ice Measurements	4	C-CORE/NRC	12	48	Could be deployed from accompanying vessel.
M2 Friction Measurements	3	IMD	4	12	Not continuous - could be doubled up.
M3 Snov Effects	3*	IMD	3	9	Propose at least 1 person be common to Tests 3/4.
M4 Ship/Ice Interaction	2	MUN/C-CORE	6	12	
M5 U/W Vieving	1	Contractor	6	6	
M6 Icebreaking Components	3*	IMD	4	12	

*Additional to shipboard team of 3

In effect the entire trials program could be conducted with three onboard persons and four on-ice persons.

The above chart indicates a team as follows:

- Contractor

  Three persons to direct on-ship operations and operate instrumentation.

- Specialist

  To deploy, operate and maintain U/W camera/submersible.

- IMD

  Three persons for on-ice work in friction, snow effects, and pre-sawn ice and subsequent analyses of data.

- C-CORE/NRC

  Up to four persons for general ice properties assessment using whatever techniques are decided

- Ship/Ice Interaction

  Two persons for measurement, observation and analysis of the ship/ice interaction process.

7.2 Test Directors

IMD proposed a joint management team comprising IMD and CCG. This should be discussed further. It is the opinion of Fleet Technology Limited that there are a few experienced test directors, most of whom are in industry, who should be contracted. These include:

- Mr. A. Keinonen (AKAC)
- Mr. P. Noble (Wartsila Marine)
- Mr. E. Makinen (Wartsila Marine)
- Mr. S. Mathews (Coldstream Maritime Inc.)
- Mr. I. Glen (Fleet Technology Limited)
- Mr. M. Edgecombe (Fleet Technology Limited)
- Mr. R. Dick (Melville Shipping Limited)

8. COSTING

It is possible only to give an estimate of costs based on the foregoing and the experience of the author.

The shipboard instrumentation is not complex and the costs will be dominated by labour and travel.

Engineering time is costed at a mean $50.00/hour, and government lab time is also costed.

A. Pre-Trial Studies

Friction Measurement Techniques	$50K
Ice Strength Measurement Techniques	$60K
U/W Viewing Pilot Test	$100K
In-Ice Pressure Sensor	$100K
Test Procedures for Manoeuvring	$20K

B. Instrumentation

Hardware	$20K	
Installation	$15K	$40K
Calibration	$ 5K	

C. Testing

Travel		$10K
Freight/Insurance		$10K
Labour	120 Mdays @ $400/day	$60K

D. Analysis of All Data $200K

Total Program Estimate	$600K - $700K

9. IDENTIFICATION OF DEVELOPMENT AREAS

9.1 General

In preparing this series of test plans, it became obvious that some of the desired measurements and tests, designed to throw further light on the ship/ice interaction and to assist in developing model full-scale correlation factors, were of a developmental nature. In some cases there is no previous experience, in others the previous experience has cast doubt on the viability of the work. In the cases noted therefore, some pre-test work is recommended.

9.2 Details of Development Areas

9.2.1 Friction Measurement

Full-scale friction factor cannot yet be measured in such a way that a representative overall friction factor can be arrived at, without major analytical developments and experimentation. All friction measurements at full-scale have been mere indexes. Direct comparison with model tank procedures is not possible at this time.

Full-scale friction varies very much from one hull area to another as a consequence of variation of snow versus ice contact as well as variation in the degree of lubrication and the contact pressure.

Hull roughness and coating material is the key to determining friction. Knowledge of the condition of the hull and the environment is sufficient for the key purpose of friction determination.

9.2.2 Ice Strength

This should be called a development area. The reason is that temperature, salinity measurements of ice together with cantilever beam tests do not give a satisfactory index of ice strength the way it influences icebreaking performance of a ship. A simple standard set of measurements should be developed or defined before these tests.

9.2.3 Process of Failure

If this is to be done beyond video visual documentation, considerable development of new techniques is involved. It should be considered that such observations be made in originally snow covered ice and in snow free ice but not in snow removed ice.

9.2.4 Under Water Vieving

This has not been successfully carried out in Canada to date. It requires development before it is feasible for expensive icebreaker trials. There are positive and negative experiences with this technique with icebreakers. A pilot experiment is recommended.

9.2.5 Testing in Ice Where Snov Has Been Removed

This is a purely developmental area. If there is snov on the ice, removal of such has not given sensible results due to the fact that the removal of snov has caused stresses and vrong flotation of ice. That has resulted in complex situations and consequently misleading results. This work was performed over ten years ago. The existing lessons should be reviewed prior to this test. The recommendation should be to find snowless ice and test in it.

9.2.6 Pre-savn Tests

This is a major effort in full-scale. Considerable analytical development is required before useful full-scale tests can be performed.

9.2.7 In-Ice Pressure Sensor

While this has been tried before, the interpretation of the results is complex and questionable. There is a need for an extensive finite element model of the ice sheet to interpret back from the ice pressure (which also has scaling problems associated with interpretation of readings) to the forces in the interface between ice and ship. Development effort is therefore required.

9.2.8 Manoeuvring Tests

This is also a development area, as no standards exist for any other testing than the basic turning circle tests. Standard test measures should be discussed and refined.

9.2.9 Breaking Out of Channel

The same comment applies to this as to most other manoeuvring tests - there are no standards generally accepted. Some analytical thinking is required before going to full-scale tests.

9.2.10 Ice Loads on Rudder/Steering Gear

Instrumentation and measurements are perhaps standard. The testing and analysis for the purpose of regulation are not. This should be considered a minor developmental area.

10. DISCUSSION OF THE TEST PLAN AND RECOMMENDATIONS

10.1 Scope of Test Plan

The principal purpose of the tests under debate is to provide scientific data for the calibration of model testing techniques. For this reason, the scope of the tests is focussed on ship performance in level and ridged ice, and on improving the accuracy of full-scale data and filling gaps in the data base.

During the workshop, a number of participants were of the opinion that if there are to be trials and a ship assigned, then the opportunity should be taken to carry out as many tests/trials as possible. Thus, local structural load measurement and global hull load measurement were originally identified as 'Priority 3' trials.

After further discussion however, these structural response requirements have been omitted for the following reasons:

(a) Their objective is to support regulatory and design development, not performance prediction from model tests.

(b) They result in an order of magnitude of cost increase due to the need for pre-instrumentation structural analysis, and the number and nature of the sensors and signal conditioning.

(c) The type of ice of most significance to structural response is multi-year ice, which is not the environmental conditions needed for the performance tests required by the principal objective.

It is our recommendation that the proposed trials remain focussed on the issue of performance and the needs of the model basin.

10.2 Environmental Measurements

In order to improve the quality of the trials results, and understanding of the physical phenomena, a number of suggestions have been made for on-ice measurements, and ship-ice interaction measurements. These have been identified in Section 9 as areas requiring at least further definition, if not significant pre-trial investigation and development. Development/investigative studies should be initiated in the priority in which the problems are discussed in Section 9, prior to the test program.

10.3 Ship Schedule

In order to satisfy the need to experience thicker, stronger ice then that in which previous tests have been conducted, the selected vessel must remain in the high Arctic as far into the Fall as is allowed. The program proposed does not fit the CCGS FRANKLIN's usual deployment other than in the February period on Newfoundland's East Coast, and we recommend investigation of the potential on other vessels.

Following the workshop, there appears to be no problems anticipated with instrumentation and no exceptional demands (e.g. docking) on the ship program.

It is our recommendation that the trials be targeted for 1990 to allow the necessary development of required measurement techniques to ensure improved quality of results.

In the meantime, IMD can benefit from resistance/speed data such as that acquired during CCG's Post Acceptance Performance Assessment (PAPA) trials as this will broaden the data base, provide the necessary experience, etc. Model tests with other vessels tested under the PAPA series should be planned.

11. BIBLIOGRAPHY

"Freeze-Up, Break-Up and Ice Thickness in Canada"; Fisheries and Environment Canada Report CL1-1-77 (1977).

"Justification for R-Class Full-Scale Trials"; Sable Maritime Limited Report 86-007 for TDC, February 17, 1988.

Proceedings of the 18th International Towing Tank Conference, October 1987, Kobe, Japan.

"R-Class Icebreaking Experiments with Model 327 and Comparison with 1:40 Scale and Full-Scale Results"; NRC Report LTR SH383, October 1984.

"R-Class Ice Trials"; Arctec Canada Limited Report ARCAN FR245C-7, August 1979.

"The Ice Climatology of the Newfoundland Bays"; Government of Newfoundland and Labrador, Seaconsult Limited, June, 1985.

ANNEX A

TRIALS SHEETS

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No. T1
CONTINUOUS LEVEL ICEBREAKING	Priority 1

Objective To determine the power required to move the vessel at continuous, steady speed through a continuous level ice cover, and to analyze the resistance.

Description
Constant power runs for 2 - 3 ship lengths in up to six ice thicknesses and a variety of snow conditions.

Time Required 3-4 days (not necessarily continuous)

Measurements Required

	RPM	Others
Thrust	2	Friction
Torque	2	Ice Thickness Properties
Ship Speed	1	Ship's Draft
		Broken Ice Piece Size

Environment Required

Level snow free ice

$\sigma_f \simeq 400$ kPa
$\sigma_f \simeq 200$ kPa
$\sigma_f \simeq 600$ kPa

Ice Thickness Range Required

0.5 -0.7 m and > 1 m
< 1 m
0.5 - 1 m

Possible Locations
Saguenay River - March; Labrador East Coast - Feb.-Apr.; Pond Inlet - January.

Special Logistic Requirements

Responsible Agency
IMD

Measurement Options
Ship's Speed (Doppler, Microwave Positioning, Camera)
Thrust (Mitchell Bearing Pressure, Other)
In Ice Pressure
Hull/Ice Friction

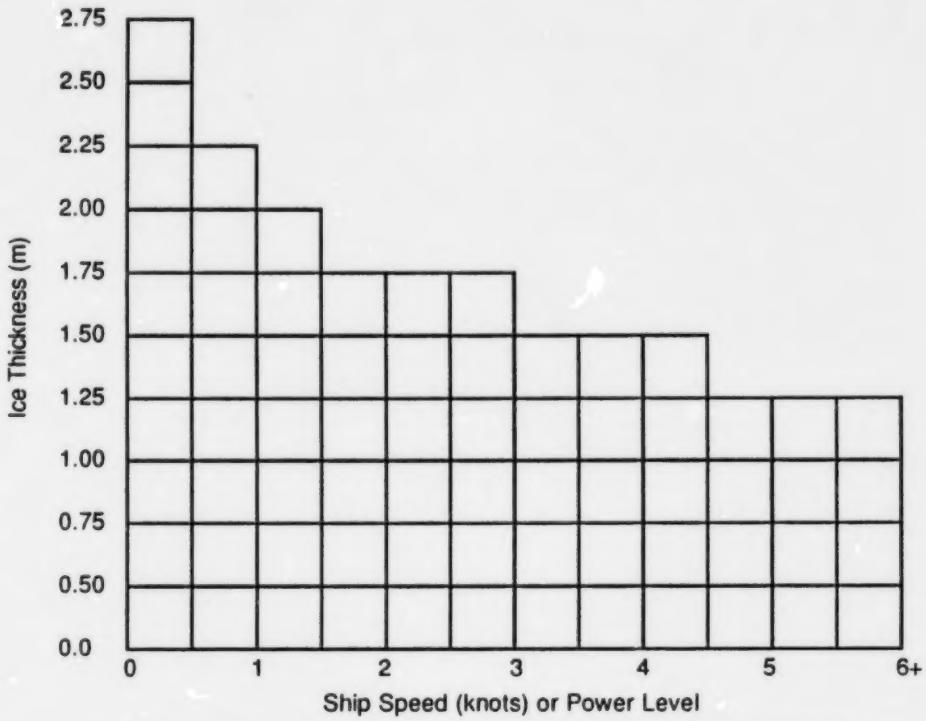
Preparatory Studies Needed

None

Notes

Analysis of data should yield speed, power curves for ice thickness and strength, deduce thrust and compare with model data in form of thrust/speed/thickness/strength plots; also snow effects.

CONTINUOUS ICE TRANSITING CAPABILITY



Enter consecutive numbers for each data point obtained.

Table 1

Data Point Number	*Ice Thickness*	*Ice Flexural Strength*	*Snow Cover*

CONTINUOUS LEVEL ICEBREAKING

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____ Wind Direction: _____

Ice Cover: _____ Wind Speed: _____

Ice Thickness: _____ Snow Cover: _____

Ice Pressure: _____ Snow Wetness: _____

Note: Other ice characteristics are to be recorded according to the selected technique. (see trial sheet)

Ice/Hull Friction Coeff.: _____

Power Setting: Port _____ Stbd. _____

Shaft RPM: Port _____ Stbd. _____

Thrust: Port _____ Stbd. _____

Torque: Port _____ Stbd. _____

Drafts: Aft _____ Fwd. _____

Ship Speed: _____ Distance Travelled: _____

Ice Failure Process Observations yes ☐ No ☐

Ice Flow Around Hull yes ☐ No ☐

Local Hull Loads Recorded yes ☐ No ☐

Remarks:

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No.
START UP TESTS	T2
	Priority 1

Objective
To measure the thrust required to overcome static friction.

Description
With vessel stationary in ice, increase power incrementally until movement is established. Repeat without snow cover.

Time Required
No additional time.

Measurements Required

	RPM (2)	Others
Thrust	2	Power Setting
Torque	2	Ice Thickness, Strength
Ship Speed		Friction, In-Ice Pressure*

Environment Required
As for Test 1

Ice Thickness Range Required
As for Test 1

Possible Locations

Special Logistic Requirements
None

Responsible Agency

Measurement Options
As for Tests 1 and 4

Preparatory Studies Needed
*In-ice pressure measurement requires studies to investigate relationship of pressure ship/ice interface.

Notes
Analysis required i.e. power level and thrust to commence motion against ice thickness, pressure, snow cover, etc.

START-UP TEST

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____ Wind Direction: _____

Ice Cover: _____ Wind Speed: _____

Ice Thickness: _____ Snow Cover: _____

Ice Pressure: _____ Snow Wetness: _____

Ice/Hull Friction Coeff.: _____

Note 1: Other ice characteristics are to be recorded according to the selected technique. (see trial sheet)

Power Setting:	Port	_____	Stbd.	_____
Shaft RPM:	Port	_____	Stbd.	_____
Thrust:	Port	_____	Stbd.	_____
Torque:	Port	_____	Stbd.	_____

Note 2: Data are to be recorded at the moment when the ship starts moving>

Remarks:

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No. T3
OVERLOAD TESTS	Priority 1

Objective
To determine propeller overload performance in full scale.

Description
Vessel tows another vessel at various power settings in open water, and with various levels of 'load' as provided by reverse thrust on towed vessel.

Time Required
1 day

Measurements Required

	RPM	Others
Thrust	2	T & Q RPM on Towed Vessel
Torque	2	Tow Rope Pull
Ship Speed	1	Drafts
		Rudder Angle Heading

Environment Required
Calm, ice free water. No wind.

Ice Thickness Range Required
N/A

Possible Locations
Anywhere where there is room and another vessel available.

Special Logistic Requirements
Second vessel. Tow line.

Responsible Agency

Measurement Options
If vessels are attached stern to stern, then data can be obtained from towed vessel also. Accurate speed measurement needed.

Preparatory Studies Needed
Study suitable vessels, possible tow loads.

Notes

OVERLOAD TESTS

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____ Wind Direction: _____

Sea State: _____ Wind Speed: _____

Drafts Aft _____ Fwd. _____

Power Setting: Port _____ Stbd. _____

Shaft RPM: Port _____ Stbd. _____

Thrust: Port _____ Stbd. _____

Torque: Port _____ Stbd. _____

Rudder Angle: _____ Heading: _____

Ship Speed: _____ Distance Travelled: _____

Towed Ship Name: _____

Drafts Aft _____ Fwd. _____

Shaft RPM: Port _____ Stbd. _____

Thrust: Port _____ Stbd. _____

Torque: Port _____ Stbd. _____

Towline Tension (mean): _____

Remarks:

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No.
RAMMING TESTS	T4
	Priority 1

Objective To determine full scale ramming performance, including progress, energy and time relationships and extraction performance.

Description

Controlled backing and ramming in thick ice and ridges. Vary speed of impact, backing distance, thrust level.

Time Required
3 days

Measurements Required

	RPM(2)	Others
Thrust	2	Motions of Vessel
		Hull/Ice Friction
Torque	2	Ridge Profiles/Consolidation
Ship Speed	1	Distances in Ram Cycle (see attached)
Broken Ice Piece Size		Interaction of ice with Propeller.

Environment Required
Thick (2 - 3 m) level ice. Ridges.

Ice Thickness Range Required
2 - 3 m level ice

Possible Locations

Special Logistic Requirements
Profiling sonar, ridge instrumentation gear. Ridge profiling gear.

Responsible Agency
To be determined.

Measurement Options

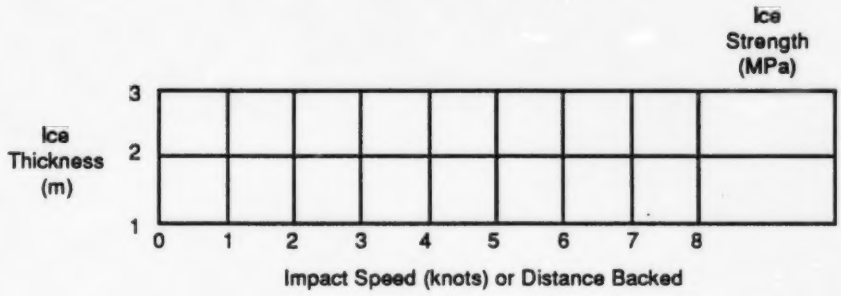
Ridge profiling instruments (transits, sonar, etc.). Accurate ship positioning (penetration, etc.) by microwave system.

Preparatory Studies Needed

There is no internationally recognized procedure for testing ramming. Preparatory study to determine the use of data and hence procedure to be used is recommended.

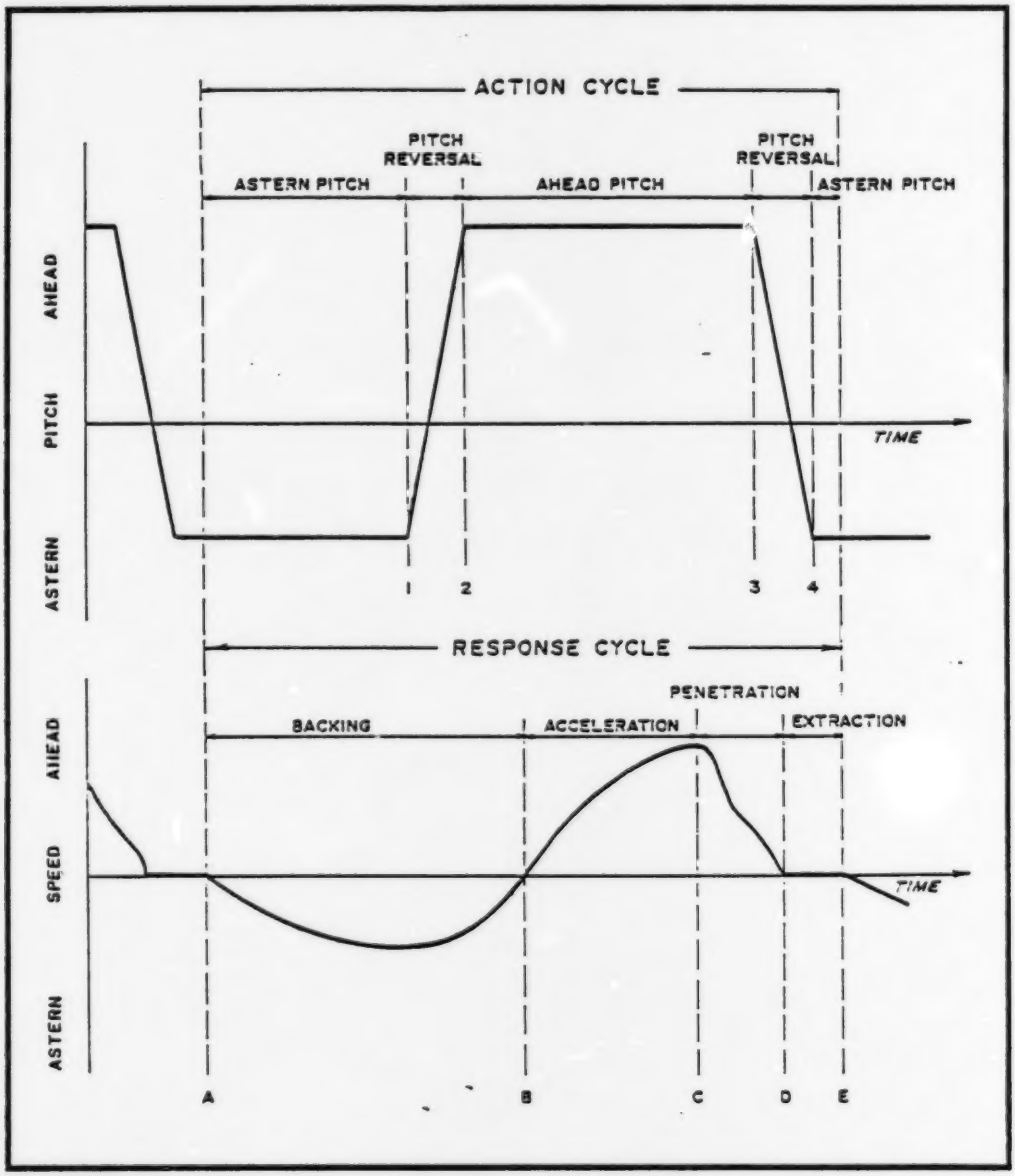
Notes

Ramming Thick Level Ice



Put "X" in box for each data point

IDEALIZED RAMMING CYCLE AND COMPONENTS



RAMMING THICK ICE

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____ Wind Direction: _____

Ice Cover: _____ Wind Speed: _____

Ice Thickness: _____ Pressure: _____

Note: Other ice characteristics are to be recorded according to the selected technique. (see trial sheet).

Drafts Aft: _____ Fwd. _____

Following parameters are to be recorded on the common time basis during ramming tests.

Shaft RPM: Port _____ Stbd. _____ Ship Speed: _____

Thrust: Port _____ Stbd. _____ Position: _____

Torque: Port _____ Stbd. _____ Motions: _____

Power Setting: Port _____ Stbd. _____ Accelerations: _____

Local loads: _____ *(if applicable)*

Global Loads: _____ *(if applicable)*

Ice Failure Process Observations yes ☐ No ☐

Ice Flow Around Hull yes ☐ No ☐

Remarks:

RAMMING PRESSURE RIDGES

Ridge Parameters							
Height (m)	Surface Width (m)						
2.4 -	15 -						
1.8 - 2.4	12 - 15						
1.2 - 1.8	8 - 12						
0.6 - 1.2	4 - 8						
0 - 1.2	0 - 4						

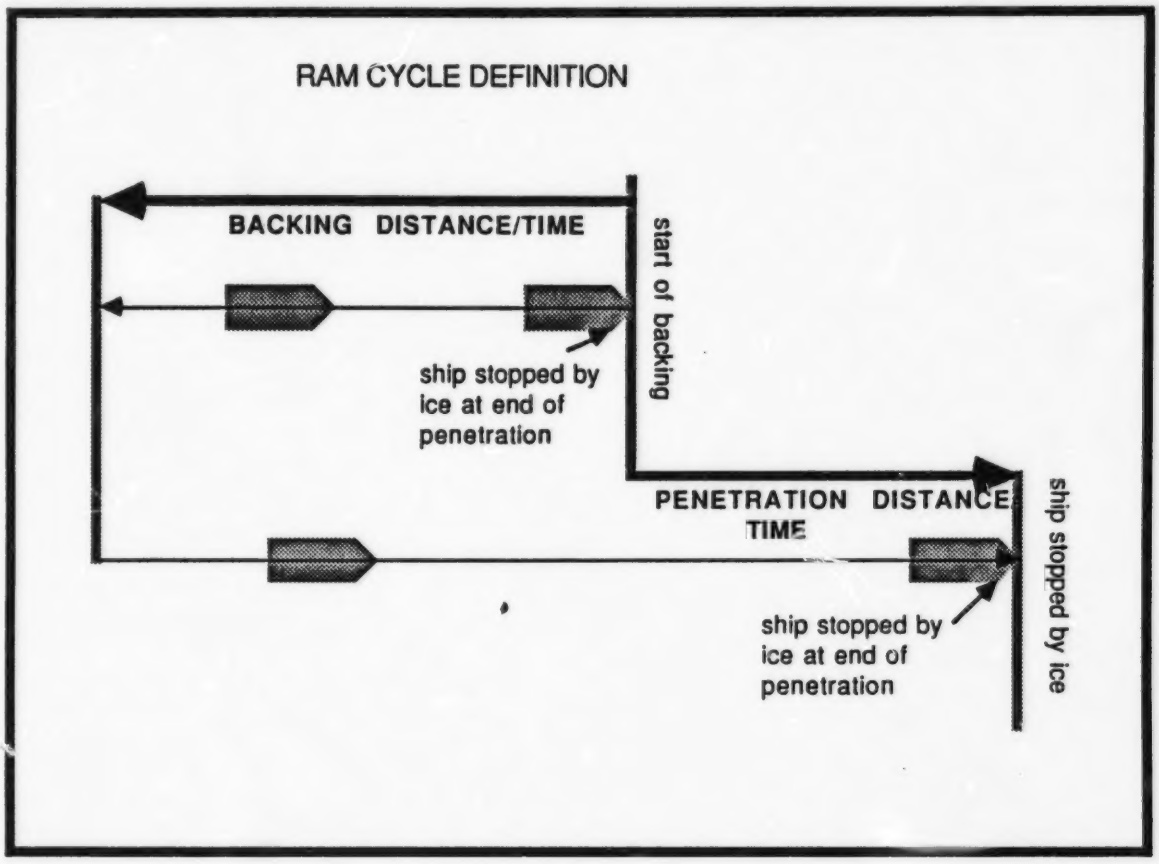
2 4 6 8 10 12

Impact Speed (knots)

Instructions: Put "X" in box for each data point obtained

Aim: 15 Data points

A.1.2.2 RAMMING PRESSURE RIDGES


RAM CYCLE DEFINITION
BACKING DISTANCE/TIME
start of backing
ship stopped by ice at end of penetration
PENETRATION DISTANCE TIME
ship stopped by ice
ship stopped by ice at end of penetration

RAM CYCLE TIME = (start of backing from first ram) - (start of backing from second ram)

RAMMING RIDGES

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____

Ridge Description: Plan View: _____

Profile View: _____

Long. Elevation: _____

Note: Other ice characteristics are to be recorded according to the selected technique. (see trial sheet).

Drafts Aft: _____ Fwd. _____

Following parameters are to be recorded on the common time basis during ramming tests.

Shaft RPM: Port _____ Stbd. _____ Ship Speed: _____

Thrust: Port _____ Stbd. _____ Position: _____

Torque: Port _____ Stbd. _____ Motions: _____

Power Setting: Port _____ Stbd. _____ Accelerations: _____

Remarks:

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name

BREAKING OUT OF CHANNEL

No. T5

Priority 2

Objective

To measure ability of vessel to break out of channel.

Description

In a broken channel proceed ahead at steady speed. Using rudder and/or differential thrust attempt to turn out of channel. Record time/distance from initiating break-out to successful completion.

Time Required

1 day

Measurements Required

	RPM
Thrust	2
Torque	2
Ship Speed	1

Others

Rudder Angle

Ship's Head

Position of Ship

Ship-Ice Interaction

Local Loads

Ice Characteristics

Environment Required

Level Ice.

Ice Thickness Range Required

0.5, 1, 1.5 m

Possible Locations

Special Logistic Requirements

Accurate Positioning Needed.

Responsible Agency

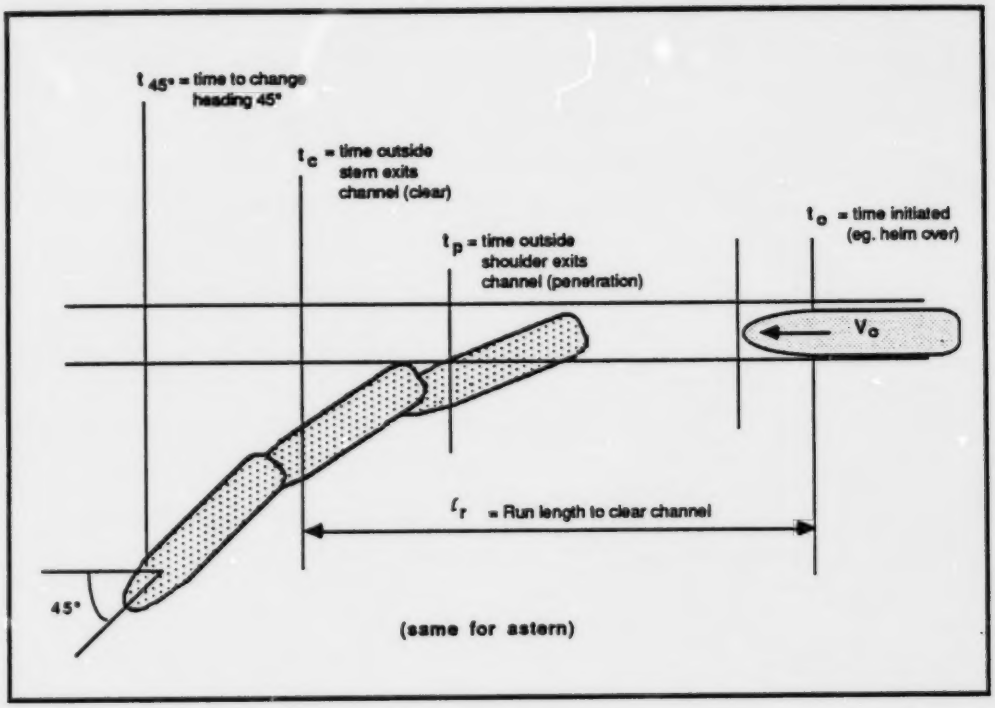
Measurement Options

Microwave positioning to assist in measuring distances, ship position.

Preparatory Studies Needed

Notes

Analysis is necessarily subjective based on times as recorded on attached.


$t_{45°}$ = time to change heading 45°
t_c = time outside stern exits channel (clear)
t_p = time outside shoulder exits channel (penetration)
t_o = time initiated (eg. helm over)
V_o
l_r = Run length to clear channel
45°
(same for astern)

#	Ahead or Astern	V_o Speed at Start	Helm	Power P/S	t_o	t_p	t_c	$t_{45°}$	l_r

BREAKING OUT OF CHANNEL

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____

Ice Cover: _____ Channel Width: _____

Ice Thickness: _____ Coverage: _____

Ice Pressure: _____

Drafts Aft: _____ Fwd. _____

		In the Channel	*In Turn*		*In the Channel*	*In Turn*
Power Setting:	Port			Stbd.		
Shaft RPM:	Port			Stbd.		
Thrust:	Port			Stbd.		
Torque:	Port			Stbd.		

Rudder Angle: _____

	Elapsed Time	*Distance Travelled*
Bow Penetration:		
Stern Exit:		
45° Out:		

Ice Failure Process Observations yes ☐ No ☐

Ice Flew Around Hull yes ☐ No ☐

Local Hull Loads Recorded yes ☐ No ☐

Remarks: *Note: Ship heading and position are to be recorded during the trial.*

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No. T6
MANOEUVRING TESTS	Priority 2

Objective
To determine the turning quality and ship-ice interaction during turning.

Description
Execute continuous turning in level ice at various throttle, thrust differential, and rudder angles in a variety of ice conditions. Execute back and fill manoeuvres.

Time Required
2 days

Measurements Required

	RPM	Others
Thrust	2	Ship's Heading Versus Time
Torque	2	Rudder Angle
Ship Speed	X	Ship's Position, Ice Characteristics, Heel Angle

Environment Required	Ice Thickness Range Required
Large area of level snow-free ice σ_f = 200, 400, 600 kPa	0, 0.5, 0.75, 1 m

Possible Locations
Saguenay River, Gulf, Gaspe, Pond Inlet

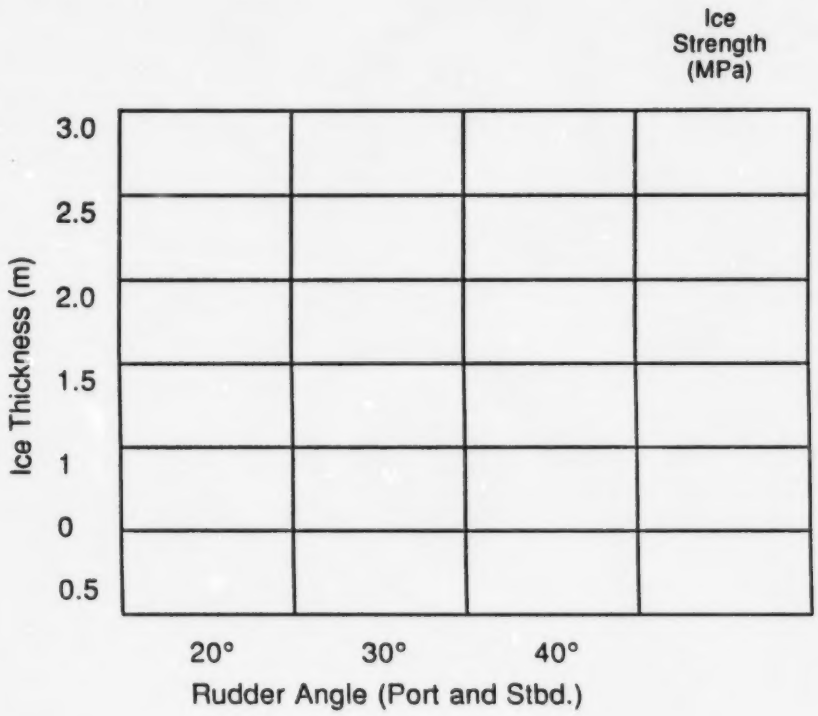
Special Logistic Requirements	Responsible Agency
Second ship required if option included	IMD

Measurement Options
1) Automatic position fixing.
2) Use of second ship to apply side tow force to assist in examining turning forces.

Preparatory Studies Needed
Further study of turning by tow of other ship has been proposed. This option is designed to determine turning moment, and merits initial study.

Notes
Analysis of data will include steady turning radius as a function of speed, ice, rudder angle, etc. Back and fill tests to be analyzed as time to turn 180^{o}.

TURNING CONTINUOUSLY IN LEVEL ICE



Notation to be used:

xxx	Full Power
xx	2/3 Power
x	1/3 Power

MANOEUVRING TESTS

Turning In Ice

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____ Wind Direction: _____

Ice Cover: _____ Wind Speed: _____

Ice Thickness: _____ Snow Cover: _____

Ice Pressure (dir.): _____ Snow Wetness: _____

Ice/Hull Friction Coeff.: _____

Note 1: Other ice characteristics are to be recorded according to the selected technique. (see trial sheet)

Power Setting: Port _____ Stbd. _____

Shaft RPM: Port _____ Stbd. _____

Thrust: Port _____ Stbd. _____

Torque: Port _____ Stbd. _____

Rudder Angle: _____ Rudder Stock Torque: yes ☐ No ☐

Heel Angle: _____ Bending: yes ☐ No ☐

Drafts: Aft _____ Fwd. _____

Ship Speed: _____ Turning Radius: _____

Time to Turn 180°:

Ice Failure Process Observations yes ☐ No ☐

Ice Flow Around Hull yes ☐ No ☐

Local Hull Loads Recorded yes ☐ No ☐

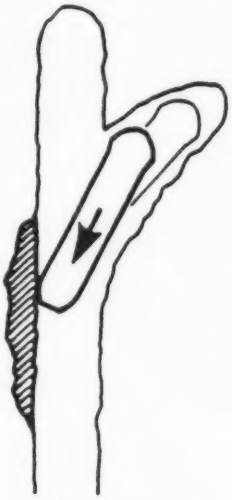
Note 2: Ship heading versus time is to be recorded during the test.

Remarks:

MODIFIED CAPTAIN'S MANOEUVRE MCM

1
Astern

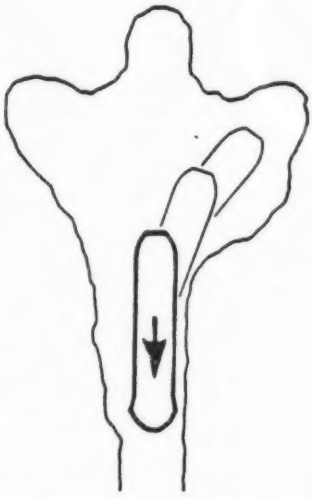
2
Ahead



3
Astern

4
Ahead

5
Astern



6
Ahead

MANOEUVRING TESTS

Back And Fill Manoeuvre

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____

Ice Cover: _____ Snow Cover: _____

Ice Thickness: _____

Note: It is recommended that this trial be performed in the same ares where the turning tests were conducted.

No. of cycles to change heading by 90°: _____ Time to turn 90°: _____

No. of cycles to change heading by 180°: _____ Time to turn 180°: _____

Maximum diameter of turn: _____

Remarks:

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No.
ICE LOADS ON RUDDERS/STEERING	T7
	Priority 2

Objective To record loads on rudders and steering gear during operations, in particular to quantify functioning of steering system in extreme conditions.

Description
Measure strains in rudder stock, hydraulic pressures, etc. during continuous icebreaking and backing and ramming.

Time Required
Time to fit - 2 days.
No special time on trials.

Measurements Required

	RPM	Others
Thrust	2	Rudder Angle
Torque	2	Hydraulic Ram Pressure
Ship Speed	X	Stock Bending Strain and Torsion
		Ice Conditions

Environment Required

Ice Thickness Range Required
All conditions

Possible Locations

Special Logistic Requirements
Calibration of rudder load desirable

Responsible Agency
CCGN

Measurement Options
Stern camera of value in classifying ice interaction.

Preparatory Studies Needed

Notes
Analysis of rudder response, pressure/time histories as a function of ship/ice interaction is required. All data on computer disc.

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No. M1
ON ICE MEASUREMENTS	Priority 1

Objective To measure such properties of ice which are known, or are reasonably expected to correlate to full scale performance of the ship and which give needed data for modelling purposes of the full scale tests.

Description

To measure relevant ice properties during trials.
To measure ridge properties.

Time Required As required noting that 2 ridges may be profiled per day.

Measurements Required

		Others
Thrust	☐	Ice Strength* Ice Pressure
Torque	☐	Ice Thickness, Salinity Temperature
Ship Speed	☐	Snow Cover, Wetness, Density

Environment Required

As required by tests described later.

Ice Thickness Range Required

See later.

Possible Locations

Special Logistic Requirements	Responsible Agency
Field Gear	C-CORE, NRC

Measurement Options

*Repeat current techniques (salinity, temperature, cantilever beams, borehole, compressive uniaxial).
In-ice pressure sensor. 'Process of Failure' investigation.
'New' NRC approach.

Preparatory Studies Needed

Need to have NRC define required on-ice measurements. Ice pressure measurement techniques to be confirmed.

Notes

Analysis requirements are to provide relevant strength measures for comparison with measurements made in the model basin.

ON ICE MEASUREMENTS

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____ Wind Direction: _____

Ice Cover: _____ Wind Speed: _____

Ice Thickness: _____ Snow Cover: _____

Ice Pressure: _____ Snow Wetness: _____

Note: Other ice characteristics are to be recorded according to the selected technique. (see trial sheet)

Remarks:

Location of Measurements

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name
FRICTION MEASUREMENTS

No. M2

Priority 1

Objective
To measure the hull condition of the ship and the properties of snow and ice sufficiently to be able to compare and correlate the various full scale tests with ships to a common data basis in terms of frictional conditions.

Description

During testing measure ship-ice friction. Use of silicon material to reproduce surface of ship is proposed by IMD. Other methods including ship panels are proposed.

Time Required
up to 1/2 day each occasion.

Measurements Required

		Others
Thrust	☐	Normal and Tangential Force
Torque	☐	Ice on Ship Hull
Ship Speed	☐	(In Ice Pressure) Option
		Ice Characteristics (Hull Roughness & Coating)

Environment Required
As tested. Snow and no snow, wet and dry

Ice Thickness Range Required
As for ship tests.

Possible Locations

Special Logistic Requirements
Test Apparatus

Responsible Agency
T.B.D.

Measurement Options
1) Friction panel installed on vessel.
2) Tribometer used on vessel's side.
3) Onboard test rig (e.g. POLAR stern or IMD 'Drum')
4) Additional in-ice pressure measurement.
5) Hull roughness and coating.

Preparatory Studies Needed

Study to evaluate cost and technical effectiveness of proposed approaches.

Notes

Analysis of data is to provide a measure that may be used to compare with model basin measurements.

FRICTION MEASUREMENTS

Surface Roughness: _____ Gauge Type _____

Readings:

Location	1	2	3	Comments

Friction Measurements: Device Descrition

Reading	Location	Ice Type	Top or Bottom	Wet/Dry	Speed	F_N	F_T	μ

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No.
SNOW EFFECT ON RESISTANCE	M3
	Priority 1

Objective
To test the ship in as many different snow conditions as possible and to document such properties of snow which are known or can be reasonably expected to influence the performance of the ship.

Description
Perform level ice resistance tests in areas with varieties of snow cover. Remove snow physically from area and repeat.

Time Required
1 - 3 days

Measurements Required

	RPM(2)	Others
Thrust	2	Friction
Torque	2	Ice Thickness; Strength
Ship Speed	1	~~Snow Thickness, Wetness/Density~~
		Hull Roughness

Environment Required
Level ice with snow cover

Ice Thickness Range Required
0.5 - 2 m

Possible Locations

Special Logistic Requirements
Snow clearing equipment.

Responsible Agency
IMD

Measurement Options

Preparatory Studies Needed
Most effective method of snow clearance.

Notes
Analysis in correlation of resistance (thrust) data with snow cover and friction measurements.

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name
SHIP-ICE INTERACTION STUDY

No. M4

Priority 1

Objective Determine the modes of failure in the ship-ice interface and the cusp dimensions around the bow to establish full scale reference for ice modelling and model testing purposes.

Description

A special focus on the ice-ship interaction will take place during icebreaking, using cameras, in-ice sensors.

Time Required
Concurrent with trials.

Measurements Required

Thrust ☐
Torque ☐
Ship Speed ☐

Others
Qualitative/Observations of Ice Failure Process (video) - synchronized with icebreaking tests.

Environment Required
Level snow-free ice and snow covered.

Ice Thickness Range Required
About 0.5 m.

Possible Locations

Special Logistic Requirements
Mount for video camera to be prepared.
Helicopter or on ice vehicle may be needed.

Responsible Agency
M.U.N.

Measurement Options
In-ice pressure sensors.
Video camera on boom or platform.

Preparatory Studies Needed
Most effective type and deployment of in-ice sensors to be studied.

Notes
Analysis will include details of the failure process by description plus possible correlation of this with in-ice pressure measurements.

SHIP-ICE INTERACTION

Test No.: _____

Date and Time: _____

Location: _____

Air Temperature: _____

Wind Direction: _____

Wind Speed: _____

Ship Activity: _____

Ice Conditions: _____

Method of Recording: _____

Observations at Time: _____

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No. M5
UNDERWATER VIEWING OF ICEBREAKING	Priority 1

Objective To observe ice flow around the hull, including determination of direction of movement, block size, etc.

Description
To deploy an underwater camera (or sonar) during icebreaking trials in level and ridged ice.

Time Required
1 day to deploy/test

Measurements Required

		Others
Thrust	☐	Visual Observation/Film
Torque	☐	Time Synchronized with Ship Test
Ship Speed	☐	Data

Environment Required	Ice Thickness Range Required
As for other tests.	As for other tests.

Possible Locations

Special Logistic Requirements	Responsible Agency
Method to deploy camera - other ship.	C-CORE

Measurement Options
Deployment of U/W Camera from R.O.V.
Deployment of U/W Camera from Second Vessel.
Deployment of U/W Camera on Seabed.
Deployment of Side Scan Sonar.

Preparatory Studies Needed
Pilot study of effectiveness and practical aspects of deployment are needed.

Notes
Analysis will include notes on piece size, flow into propellers, number of ice encounters, point at which ice surfaces, etc.

UNDERWATER VIEWING OF ICEBREAKERS

Test No.: _____

Date and Time: _____

Location: _____

Ship Activity: _____

Ice Conditions: _____

Location / Type of Viewing Device: _____

(sketch as necessary)

Notes Concerning Viewing System: _____

FULL SCALE TRIALS OF AN ICEBREAKER

Trial Name	No. M6
ICEBREAKING RESISTANCE COMPONENTS	Priority 2

Objective To determine the breaking and submergence components of level ice resistance, for model testing purposes.

Description
To run the ship at constant power through pre-sawn level ice. Two ship lengths maximum run needed per power setting.

Time Required
2 days

Measurements Required

	RPM	Others
Thrust	2	Friction
Torque	2	Ice Properties
Ship Speed	X	~~Ship's Draft~~

Environment Required
Thin Level Ice, Snow Free
Identical to that for Test 3
σ_f = 200 & 500 kPa

Ice Thickness Range Required
0.4 - 0.75 m

Possible Locations
Same site as for Continuous Icebreaking Trials

Special Logistic Requirements
Field party to pre-saw ice; Ditch-Witch.

Responsible Agency
IMD (C-CORE)

Measurement Options
Ice cutting by saw or thermal drill. Ditch-Witch
Ship speed by microfix system, Doppler Log, o/s camera.

Preparatory Studies Needed
Ice peice sizes to be cut.

Notes
Although this is a priority 2 item, it should be waived is time is short. Need to measure performance in identical ice, not pre-sawn. Analysis should separate ice-breaking resistance from ice clearing resistance by comparison with results from unsawn ice.

ICEBREAKING RESISTANCE COMPONENTS

Test No.: _____

Location: _____ Date and Time: _____

Air Temperature: _____ Wind Direction: _____

Wind Speed: _____

Drafts: Aft _____ Fwd. _____

Pre Sawn Ice Pattern
(sketch)

Piece Size